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Peat Resources of Selected Wetlands on Block Island, Rhode Island

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PEAT RESOURCES OF SELECTED WETLANDS ON BLOCK ISLAND, RHODE ISLAND

BY

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ABSTRACT

All freshwater wetlands of Block Island, Rhode Island larger than 0.05 ha were delineated from 1:12,000-scale panchromatic aerial photographs and classified on the basis of dominant vegetation life-form, soils and water regime. The 216 wetlands cover 121.23 ha of the 2809.71 ha island and range in size from 0.05 to 7.89 ha. Thirteen wetland subclasses are present. Nonvegetated open water, robust deep marsh, robust shallow marsh and bushy shrub swamp are the four most extensive wetland subclasses and comprise 75% of the total wetland area.

The energy resource of post-glacial peat deposits in seven of the larger (0.9-7.89 ha) and most accessible wetlands was determined from 56 stratigraphically continuous cores and peat isopach maps. Maximum peat depths in these wetlands ranged from 3 to 12 m. Three peat types were found: moss, reed-sedge, and sedimentary peat. No relationship was found between wetland subclasses and the quality, thickness or type of subsurface peat.

Moisture-free (MF) proximate, ultimate, and calorific analyses from every investigated wetland indicate moss peat yields 8400-9550 BTU/lb and contains 9-19% ash. Reed-sedge has 17-34% ash and yields 6500-8500 BTU/lb, while sedimentary peat contains 36-54% ash and yields 4700-6400 BTU/lb. An inverse relationship (99.5 significance level) exists between BTU/lb (MF) and ash and is defined by the

equation: BTU/lb = -106.76 (% ash) + 10370.21.

The seven wetlands contain 92,250 tonnes of peat (35% moisture). Fuel-grade peat (>8000 BTU/lb MF, <25% ash; U.S. D.O.E., 1980) occurs in three wetlands and amounts to 27,360 tonnes. This quantity of peat could fuel a one megawatt electrical generating power plant for 5.25 yr or heat 100 homes for 20-38 yr. An additional 24,210 MT of fuel-grade peat might be present in zones of no recovery from four of these wetlands and would increase power plant resource by 4.65 yr or the home heating resource by 16-30 yr.

ACKNOWLEDGMENTS

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I am indebted to A. Pickart for extensive assistance in freshwater wetland classification and for introducing me to an appreciation of wetlands. S. Crone was an excellent field assistant and good companion during work in wetlands studied in detail. The citizens of Block Island were helpful in providing transportation, access to property and local knowledge of wetlands on the island.

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This thesis is dedicated to my parents, Ronald and Pauline Peters, in appreciation of their financial and continual moral support throughout my academic quest.

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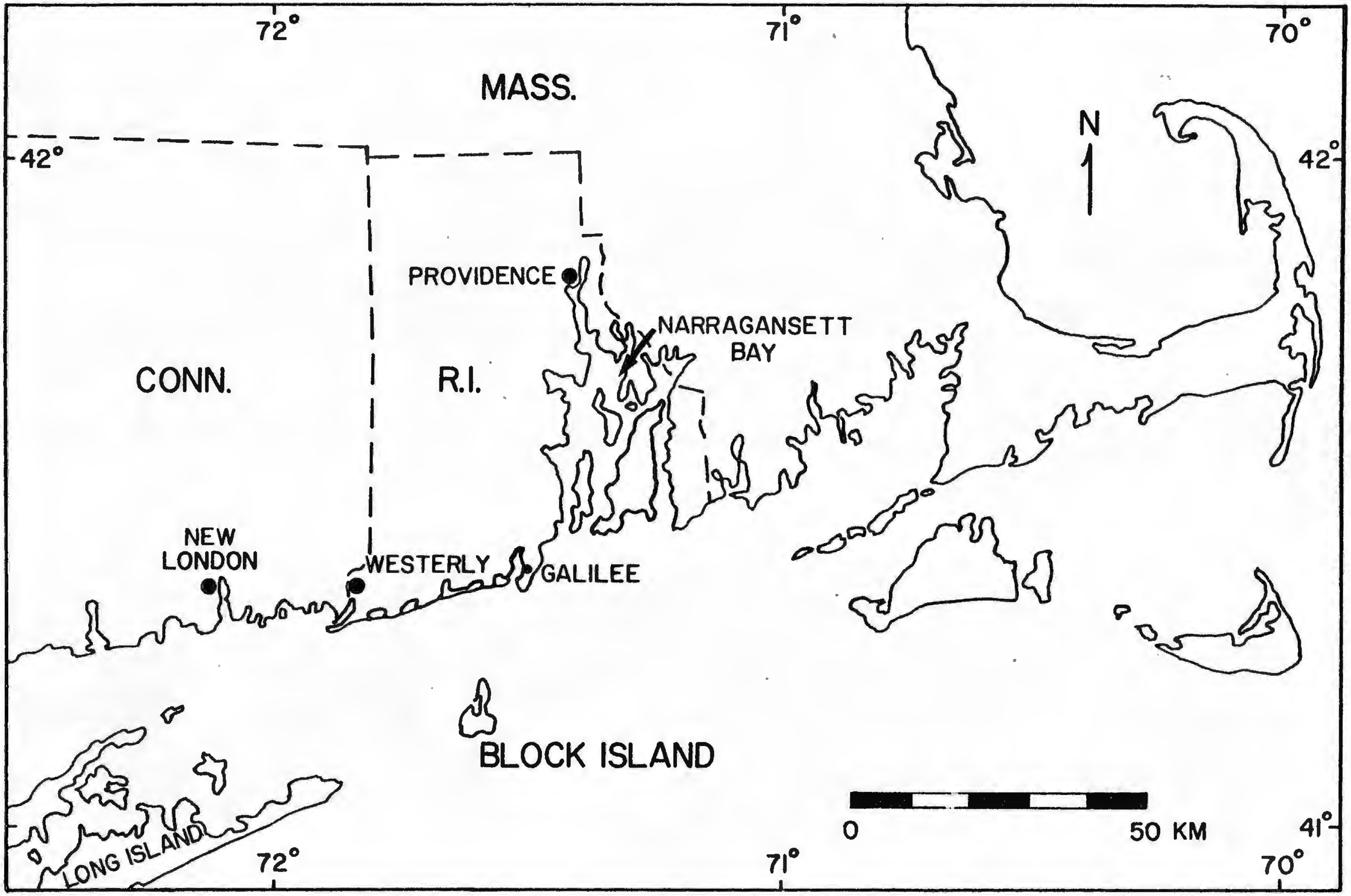
INTRODUCTION

Block Island, Rhode Island, located 25 km south of mainland Rhode Island (Fig. 1) is only accessible by air or ferry services. Four percent of the island is light-density residental (MacConnell, 1974) with a population fluctuating from 620 year-round residents (U.S. Bureau of Census, 1980) to several thousand people during summer months. MacConnell (1974) classifies 5% of the island as recreational, 69% agricultural or open land, 3% forested and the remaining 16% as varieties of open water, salt water and fresh water wetland.

In 1978, as national reserves of petroleum fuel sources became less available and accessible, the United States established a National Energy Act which emphasizes the development and utilization of alternate energy sources such as: coal, geothermal, nuclear, solar, hydroelectric and peat (U.S. D.O.E., 1979). In the past, many of these resources could not compete with petroleum reserves. Contained within wetlands of the United States is the world's fourth largest peat resource (Moore and Bellamy, 1974), most of which are located in areas that otherwise lack local coal and petroleum fuel sources (U.S. D.O.E., 1979).

Peat deposits in the freshwater wetlands of Block Island are an indigenous and potential source of fuel for the power

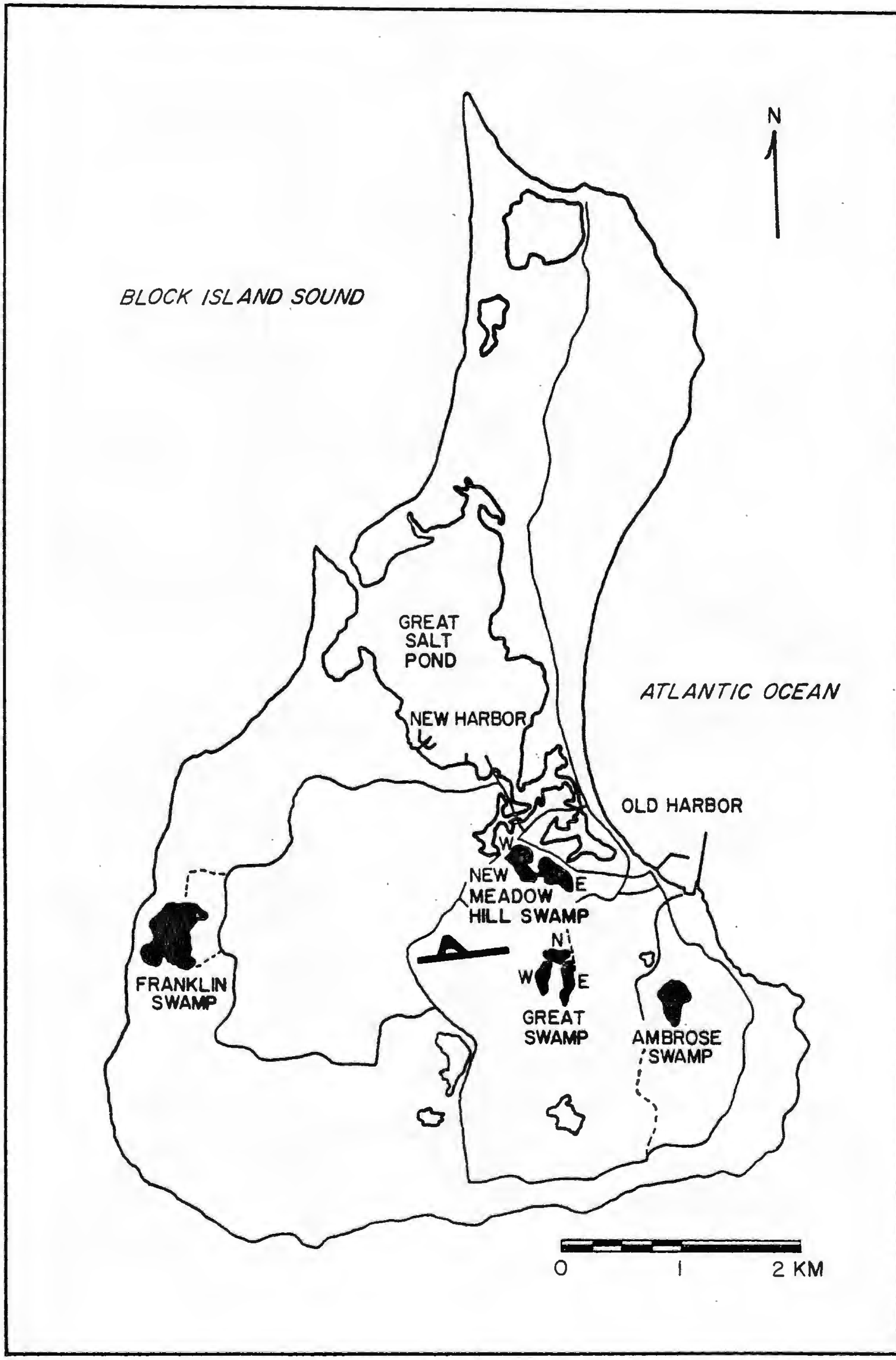
Fig. 1. -- Location map of Block Island, Rhode Island



72°
71°
70°
42°
41°
MASS.
CONN.
R.I.
PROVIDENCE
NARRAGANSETT
BAY
NEW
LONDON
WESTERLY
GALILEE
BLOCK ISLAND
LONG ISLAND
N
0
50 KM

plant and domestic heating of the island community. Electricity is currently generated by a disel-fired power plant and wind mill at New Meadow Hill Swamp (Fig. 2) with all fossil fuels being ferried 25 km from Galilee, Rhode Island. However, peat deposits of the island lack the scientific documentation essential for utilization as a fuel source. The purpose of this study is to classify and inventory the freshwater wetlands of Block Island (Fig. 3) and to determine the extent, stratigraphy and fuel quality of peat in the larger and most accessible wetlands: Ambrose, Franklin, Great and New Meadow Hill Swamps (Fig. 2). Identification of peat stratigraphy, a necessity for fuel resource evaluation, is also used to interpret the successional history of the investigated wetlands.

Fig. 2.--Location of investigated wetlands: Ambrose and Franklin Swamps; East, West and Neptune Segments of Great Swamp and East and West parts of New Meadow Hill Swamp.


N
BLOCK ISLAND SOUND
GREAT
SALT
POND
NEW HARBOR
ATLANTIC OCEAN
OLD HARBOR
W
E
NEW
MEADOW
HILL SWAMP
N
W
E
FRANKLIN
SWAMP
GREAT
SWAMP
AMBROSE
SWAMP
0
1
2 KM

GEOLOGIC SETTING

The glacial deposits overlying Late Cretaceous clays of Block Island have been interpreted to result from at least several episodes of late Pleistocene glaciation (Kaye, 1960; Woodworth, 1934; Sirkin, 1976). The most recent interpretation (Sirkin, 1981) of the island's glacial stratigraphy distinguishes two drift sequences (Lighthouse Cove Formation and New Shoreham Formation) resulting from separate Wisconsinan ice advances. Till fabric and provenance of till clasts indicate the lower, Lighthouse Cove Formation was derived from an Altonian (>43,000 yr BP) ice lobe that moved south along the Narragansett Embayment while the upper, New Shoreham Formation was deposited by a Woodfordian (<21,750 yr BP) ice lobe that crossed southwestern Rhode Island and southeastern Connecticut.

The Lighthouse Cove Formation consists of the Old Harbor Sand and the Mohegan Bluffs Till (Sirkin, 1981). Old Harbor Sand, an outwash unit, was deposited as the Altonian lobe advanced towards Block Island. The overlying Mohegan Bluffs Till was deposited by ablation as the Altonian ice lobe advanced beyond and receded from Block Island (Kaye, 1960; Sirkin, 1976, 1981).

An erosion surface separates the Lighthouse Cove and New Shoreham Formations (Sirkin, 1981). The New Shoreham Formation consists of outwash sands and gravels (Isaacs

Corner Sand) up to 16.7 m thick, which are generally truncated by 1.7-3.4 m of Old Town Till (Sirkin, 1981). The bluffs and cliffs surrounding most of Block Island have eroded into the superimposed Lighthouse Cove and New Shoreham Formations.

The hydrologic profile of Block Island is comprised of upper perched water bodies, lower perched water zones, and the main zone of saturation (Fig. 4). Superimposed New Shoreham and Lighthouse Cove Formations are probably responsible for the complex hydrology. The abundant, upper perched water bodies occur at the surface as ponds [wetlands] and are isolated from the underlying lower perched water zone and main zone of saturation by till, clay or peat aquicludes (Hansen and Schiner, 1964). Saturated thickness of the upper perched water bodies is less than 6.1 m. The lower perched water zone is underlain by clay or compact till aquicludes or is interconnected with the main zone of saturation. Hansen and Schiner (1964) consider the surface of the lower perched water zone to represent the water table of the main zone of saturation.

The last ice advance and subsequent deglaciation are responsible for the present topography of Block Island (Sirkin, 1976, 1981). Recessional moraines at the north and south ends of the island are separated by Great Salt Pond (Sirkin, 1981). Deep meltwater channels, represented by Rodman Hollow and others along Mohegan Bluffs, drained southward from the southern, Beacon Hill Moraine. Shallower meltwater drained to the north and west of this moraine. Depositional and erosional features in drumlins concentrated around Great Salt Pond indicate minor ice margin fluctuations prior to the final recession from the Corn Neck Moraine at the north end of the island (Sirkin, 1981).

A date for deglaciation of Block Island has not been established by radiocarbon-dated pollen stratigaphy. However, four pollen profiles (one from Great Swamp) have been correlated to similar, dated-pollen stratigraphy from Long Island (Sirkin and Stuckenrath, 1980) and are inferred to indicate Block Island was ice free 21,000 yr BP (Sirkin, 1981).

A basal herb zone in three Block Island pollen profiles signifies tundra vegetation and is overlain by a spruce zone (Sirkin, 1976, 1981). In the Great Swamp, the two zones are separated by a thin silt unit, indicating tundra occupied the basin prior to a lake stage containing the spruce pollen (Sirkin, 1976). Tundra was present on the southern part of the island while the ice margin was at the Corn Neck Moraine (Sirkin, 1981). The upper spruce zone of a pollen profile near the Corn Neck Moraine has a date of 11,900 +/- 100 yr BP (Sirkin, 1981) which is a minimum age for the origin of freshwater wetlands on Block Island.

METHODS

The freshwater wetlands of Block Island were classified according to a modified version (Golet, 1979) of a classification system developed by Golet and Larson (1974) for the freshwater wetlands of the glaciated northeast. This system separates wetlands into 8 classes and 26 subclasses (Table 1) on the basis of soils, water regime and life-form of dominant vegetation.

The life-form (Fig. 5), or height, branching pattern and foliage density of vegetation is recognizable on aerial photographs and this permits classification of wetlands to the class level. Subforms of vegetation (Fig.5) distinguish wetland subclasses. Identification of vegetation subforms (as defined by a life-form's structure, ecology and stand density) is not always possible from aerial photographs and requires field checks.

The freshwater wetlands of Block Island exceeding 0.05 ha (0.12 acre) were delineated and classified from 25 panchromatic aerial photographs (1:12,000 scale) taken on April 23, 1975. Oblique color and color-infrared photographs from an helicopter at an altitude of 150-400m facilitated classification.

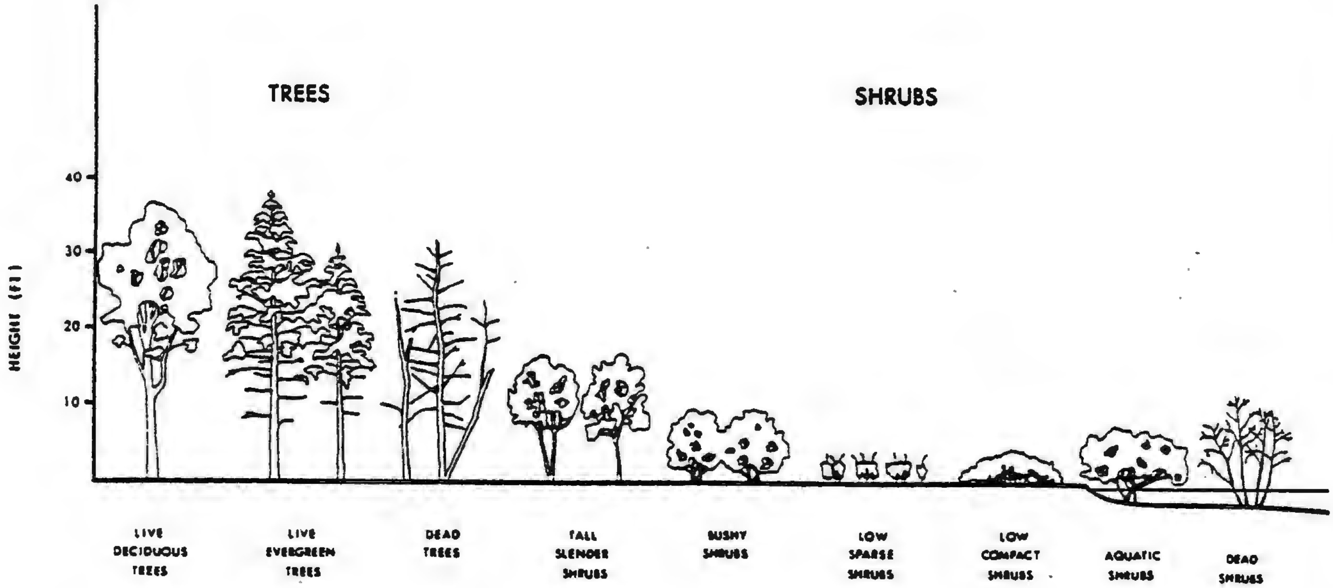
The wetland boundaries were photogrammetrically transferred to a 1:12,000 scale topographic base map obtained from the Coastal Resources Center, University of Rhode Island. Altitude variation of the photographing

Table 1.--Freshwater wetland classes and subclasses of the glaciated northeast (Golet, 1979)

WETLAND CLASS	WETLAND SUBCLASS	SYMBOL
Open Water	Vegetated	OW-1
	Nonvegetated	OW-2
	Shallow vegetated	OW-3
Deep Marsh	Dead woody	DM-1
	Shrub	DM-2
	Sub-shrub	DM-3
	Robust	DM-4
	Narrow-leaved	DM-5
	Broad-leaved	DM-6
Shallow Marsh	Robust	SM-1
	Narrow-leaved	SM-2
	Broad-leaved	SM-3
Meadow	Ungrazed	M-1
	Grazed	M-2
Shrub Swamp	Deciduous sapling	SS-1
	Bushy	SS-2
	Compact	SS-3
	Aquatic	SS-4
	Evergreen sapling	SS-5
Wooded Swamp	Deciduous	WS-1
	Evergreen	WS-2
Fen	Emergent	F-1
	Low shrub	F-2
Bog	Emergent	BG-1
	Shrub	BG-2
	Forested	BG-3

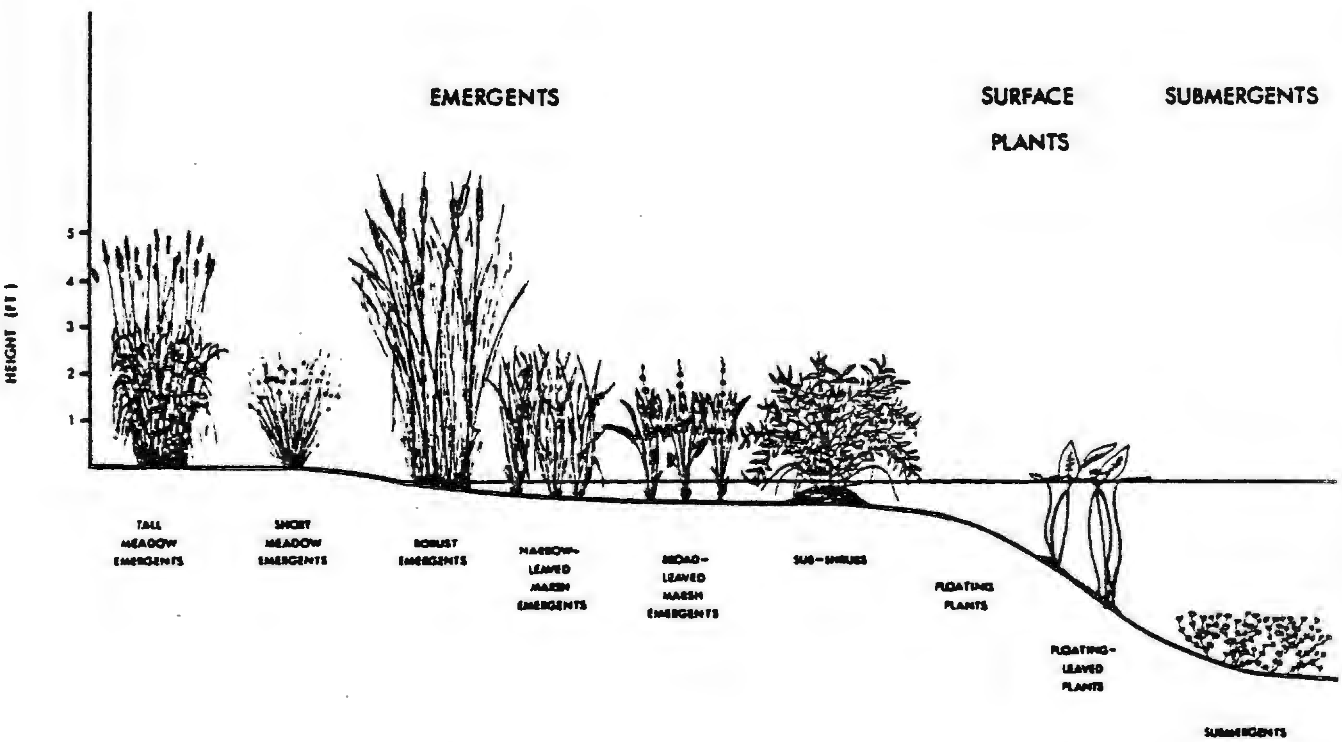
Fig. 5 — Life-forms and subforms of freshwater wetland vegetation. Life-forms include: trees, shrubs, emergents, surface plants and submergents (note difference in vertical scales of A and B). The respective sub-forms of vegetation are labeled at the bottom of drawings A and B (from Golet and Larson, 1974).

A



TREES
SHRUBS
HEIGHT (FT)
40
30
20
10
LIVE DECIDUOUS TREES
LIVE EVERGREEN TREES
DEAD TREES
TALL SLENDER SHRUBS
BUSHY SHRUBS
LOW SPARSE SHRUBS
LOW COMPACT SHRUBS
AQUATIC SHRUBS
DEAD SHRUBS

B



EMERGENTS
SURFACE PLANTS
SUBMERGENTS
HEIGHT (FT)
5
4
3
2
1
TALL MEADOW EMERGENTS
SHORT MEADOW EMERGENTS
ROBUST EMERGENTS
NARROW-LEAVED MARSH EMERGENTS
BROAD-LEAVED MARSH EMERGENTS
SUB-SHRUBS
FLOATING PLANTS
FLOATING-LEAVED PLANTS
SUBMERGENTS

aircraft, camera tilt at the instant of exposure and variation in local relief are the major sources of scale distortion in aerial photographs (Avery, 1977). Effects of tilt were reduced by using the central third of the photographs. Altitiude and relief distortions were diminished by optically rectifying the photograph scale to the base map scale with a Zoom Transfer Scope. Wetland and subclass areas (App. 1) were measured on the resulting 1:12,000 scale wetland map with a rolling disk planimeter.

The larger and most accessible wetlands (Ambrose, Franklin, Great and New Meadow Hill Swamps) were selected for peat resource investigation (Fig. 2). The major axes of these wetlands were determined in the field and from aerial photographs. Stratigraphically continuous cores were taken to the limit of penetration with an Eijkelkamp gouge corer or with a Davis peat corer at 25, 50 or 100 m intervals along these axes. The gouge corer proved to be more satisfactory and efficient than the Davis corer. Samples from the gouge corer are 6 cm by 100 cm long while those of the Davis corer are only 2 cm by 25 cm. The entire core was placed in trays and wrapped in plastic for subsequent classification and logging. Depth from the surface to glacial sediment was determined with a steel probe rod between core sites and at various other sites throughout the wetland. Location of core and probe sites was determined by a measuring tape and compass bearings.

Wetland, depth contour and peat isopach maps were constructed for each investigated wetland from aerial photographs and field data with the Zoom Transfer Scope and an Art-O-Graph. Depth contour maps discount penetration of glacial sediments by the corers and probe. Peat isopach maps exclude a zone of no recovery present at the top of all cores.

In situ peat volume for each investigated wetland was calculated from the peat isopach maps. Surface area inside the wetland boundary and within isopach contour intervals was determined with the rolling disk planimeter. The resulting areas were multiplied by the contour interval (1 m) to obtain the volume of individual thickness intervals. The product of peat volume and peat density provide the tonnage of peat in each wetland.

The use of different criteria in defining peat types has resulted in various peat classification systems. Degree of plant fiber decomposition is the basis for peat classification by the Von Post system (Davies, 1945) and the Soil Conservation Service's classification of histosols (organic soils which include peat) (Soil Survey Staff, 1975). Some systems define peats according to depositional-water regime (Moore and Bellamy, 1974) or by plant constituents (Dachnowski, 1926; Rigg, 1940).

Other peat resource investigations (Edgerton, 1969; Cameron, 1970a, 1970b, 1975; Davis et al., 1980) use the U.S. Bureau of Mines (1969) classification system. This system separates peat into three general types on the basis of botanical composition: moss peat, reed-sedge and peat humus. The names, moss peat and reed-sedge, describe the plant constituents making up these peat types (Fig. 6). Plant remains in peat humus are so decomposed that identification of original vegetation is impossible. Woody material may be present in all three peat types. A fourth type, sedimentary peat (Fig. 6), is described by Cameron (1970a) and consists of the remains of surface and submergent plants (Fig. 5). Sedimentary peat most commonly occurs at the bottom of peat deposits.

The U.S. Bureau of Mines (1969) classification system and the sedimentary peat type of Cameron (1970a) were used to classify and log (App. 2A-L) the peat cores from the investigated wetlands. Eight stratigraphically continuous cores representative of peat types from each wetland were selected for fuel analysis. These cores were shipped to the U.S. Department of Energy Coal Preparation Laboratory in Pittsburgh, Pennsylvania where energy analyses were performed.

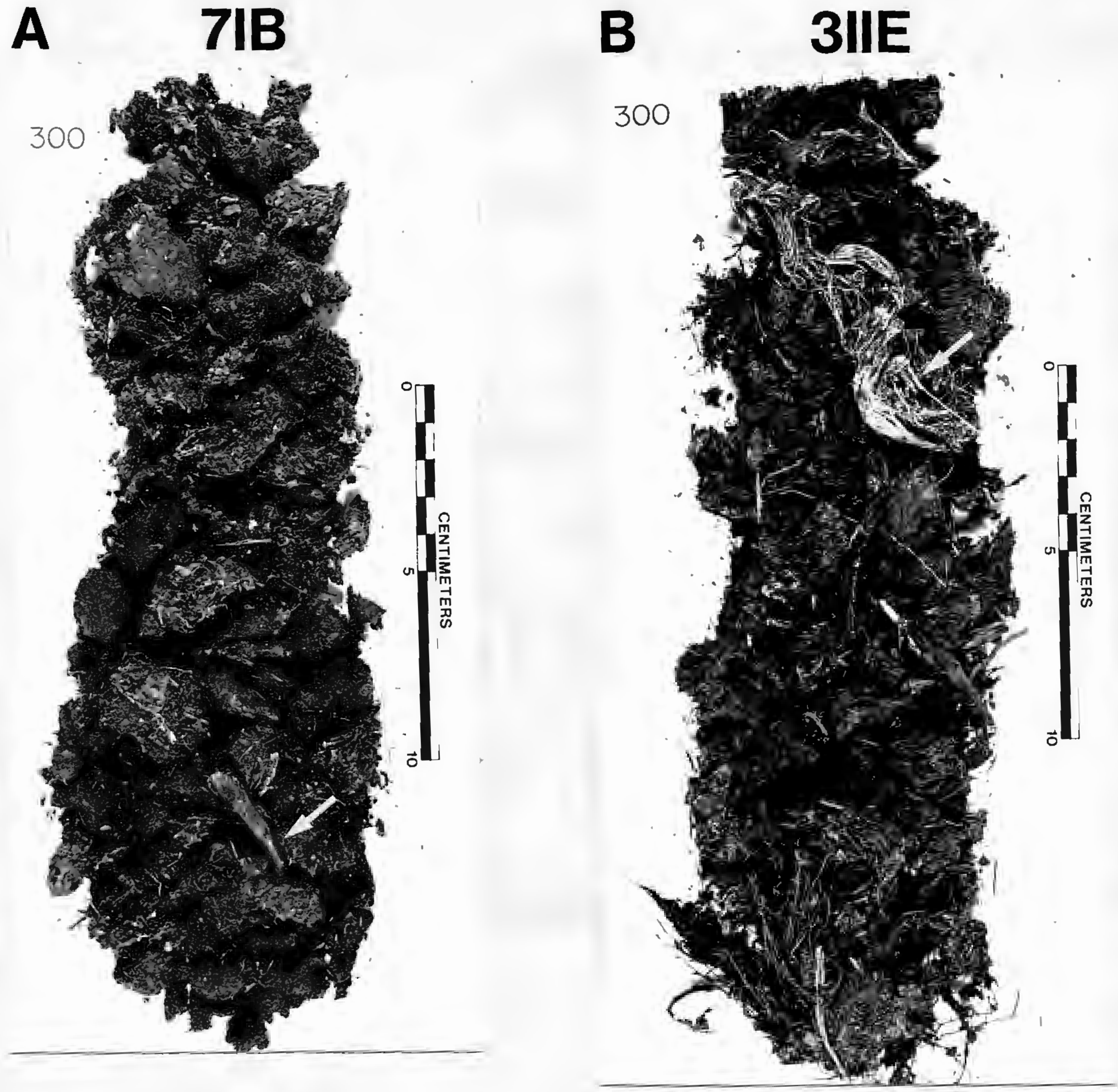
Fig. 6.—Air-dried examples of peat types

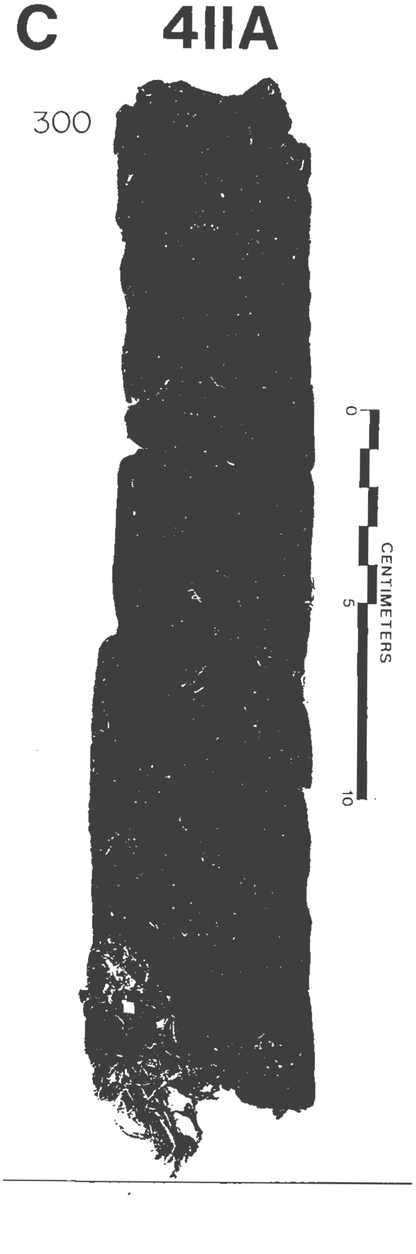
A. Moss peat: Fibrous, poorly decomposed peat consisting primarily of _Sphagnum_ mosses from bogs. Twig indicated by arrow. All peat types can contain woody material. Core 7IB; Ambrose Swamp.

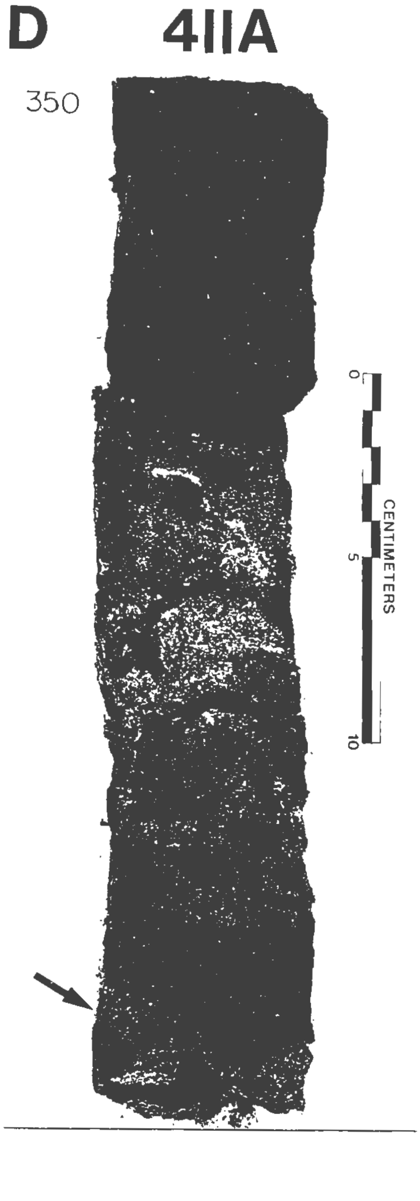
B. Reed-sedge: fibrous, partially decomposed peat made up of emergent vegetation from marshes or fens. Arrow indicates cattail (_Typha_ spp.) fragment. Core 3IIE; West New Meadow Hill Swamp.

C. Sedimentary peat: finely decomposed peat formed from surface and submergent vegetation of open water. Most commonly occurs at bottom of peat peat deposits. Core 4IIA; Franklin Swamp.

D. Sedimentary peat-glacial sediment contact (indicated by arrow). Light colored specks in dark sedimentary peat are grains of sand and contribute to ash content. Glacial sediment is medium grained sand.


A
71B
300
0
5
10
CENTIMETERS
B
311E
300
0
5
10
CENTIMETERS


C
411A
300
0
5
10
CENTIMETERS


D
411A
350
0
5
10
CENTIMETERS

RESULTS

Freshwater Wetland Inventory

A description of the freshwater wetlands found on Block Island follows. Except for fens (Jeglum et al., 1974), definitions of wetland classes and subclasses are from Golet and Larson (1974). Refer to Table 2 for the total area of each class and subclass, Figure 5 for vegetation life-forms and subforms, Figure 3 for the location of individual wetlands and Appendix 1 for the area of individual wetlands.

The 216 freshwater wetlands mapped on Block Island cover a total of 121.23 ha (299.44 acres) and range in size from 0.05 to 7.89 ha. One hundred and ninety one (45% total area) wetlands are smaller than a hectare. Seven classes and 13 subclasses of freshwater wetland are present (Table 2) along with four areas of deepwater habitat (water bodies exceeding 2 m in depth or larger than 8 ha in area; Cowardin et al., 1979). Deepwater habitats include: Sands, Fresh, Middle and Sachem Ponds (depths from Guthrie and Stolgitis, 1977).

Open Water (OW).-- Open water is the most abundant class on Block Island constituting 40.7% of the total wetland area. This term is applied to freshwater bodies less than 2 m in depth. Surface plants and submergents are the life-forms (Fig. 5) of vegetation dominating this wetland class.

Vegetated open water (OW-1): Floating-leaved plants

Table 2.-- Freshwater wetland classes and subclasses of Block Island, Rhode Island

WETLAND CLASS	WETLAND SUBCLASS	SYMBOL	AREA (ha)	% TOTAL AREA
Open Water	Vegetated	OW-1	6.59	5.4
	Nonvegetated	OW-2	42.76	35.3
Deep Marsh	Sub-shrub	DM-3	12.32	10.2
	Robust	DM-4	22.62	18.7
	Narrow-leaved	DM-5	2.41	2.0
Shallow Marsh	Robust	SM-1	12.82	10.6
	Narrow-leaved	SM-2	0.54	0.4
Meadow	Ungrazed	M-1	0.63	0.5
Shrub Swamp	Bushy	SS-2	10.93	9.0
	Aquatic	SS-4	0.81	0.7
Fen	Emergent	F-1	1.18	1.0
Bog	Emergent	BG-1	1.26	1.0
	Shrub	BG-2	6.36	5.2
			121.23	100.0

such as white water lily (Nymphaea odorata) and spatterdock (Nuphar spp.) and floating plants such as duckweeds (Lemna spp.) are the subforms of vegetation found in vegetated open water (Fig. 7). Two subclasses of vegetated open water are recognized in Golet (1979) (Table 1); however, since water depths were not measured in this study, all areas were classified simply vegetated open water (OW-1).

Nonvegetated open water (OW-2): Nonvegetated open water, the largest wetland subclass on Block Island, may contain submergent vegetation such as pondweeds (Potamogeton spp.), but surface vegetation is absent (Fig. 8). Both subclasses of open water (OW-1, OW-2) may encompass entire wetlands (#133, 141) or occur in association with other subclasses as in Fresh Swamp (#126) and Peckham Pond (#121).

Deep Marsh (DM).-- Deep marsh is the second largest wetland class on Block Island and makes up 31.41% of the total wetland area. Emergents are the dominant vegetation. Average water depth is between 15 and 100 cm during the growing season. Three subclasses of deep marsh are present on Block Island.

Sub-shrub deep marsh (DM-3): Water willow (Decodon verticillatus), a sub-shrub, is the solitary species comprising DM-3. This subclass most commonly occurs along the edges of open water (Fig. 10).

Robust deep marsh (DM-4): Cattails (Typha spp.) and reed (Phragmites australis) are the robust emergents that

Fig. 7.—Vegetated open water (OW-1). White water lily (Nymphaea odorata) in foreground is the characteristic vegetation of this subclass. Island at upper right (DM-3) consists of Decodon verticillatus. View is to east across Siah's Swamp (#69).

Fig. 8.—Nonvegetated open water (OW-2). The most abundant subclass on Block Island. Eastward aerial view of John E's Pond (#146) and Payne Pond (#150).


DM-3
OW-1

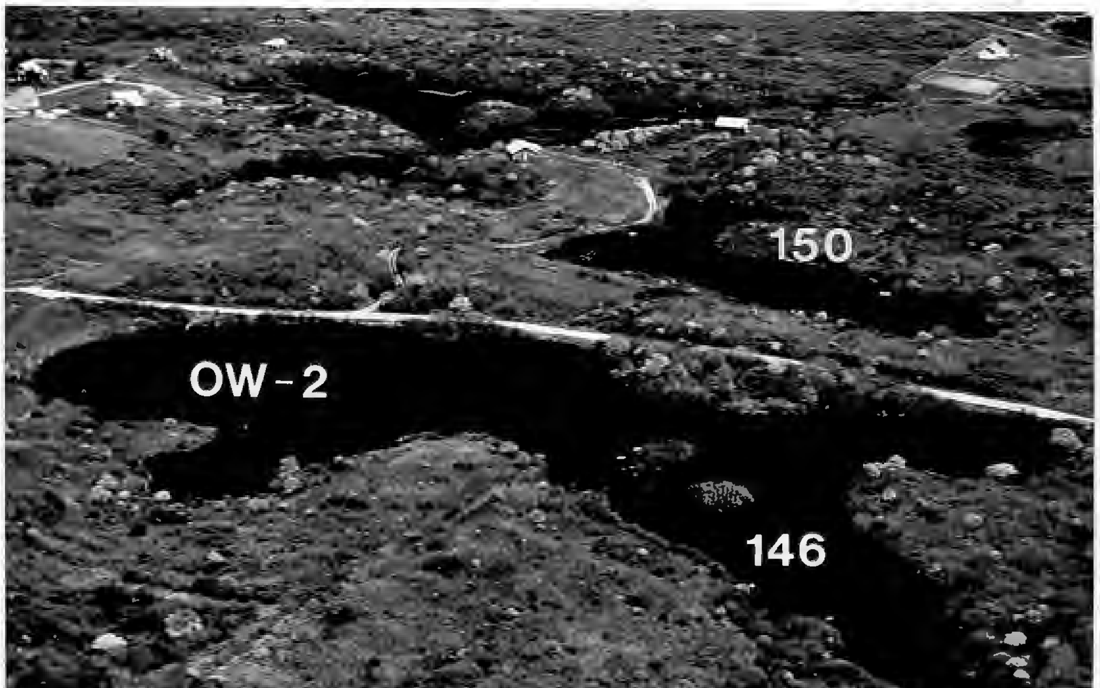
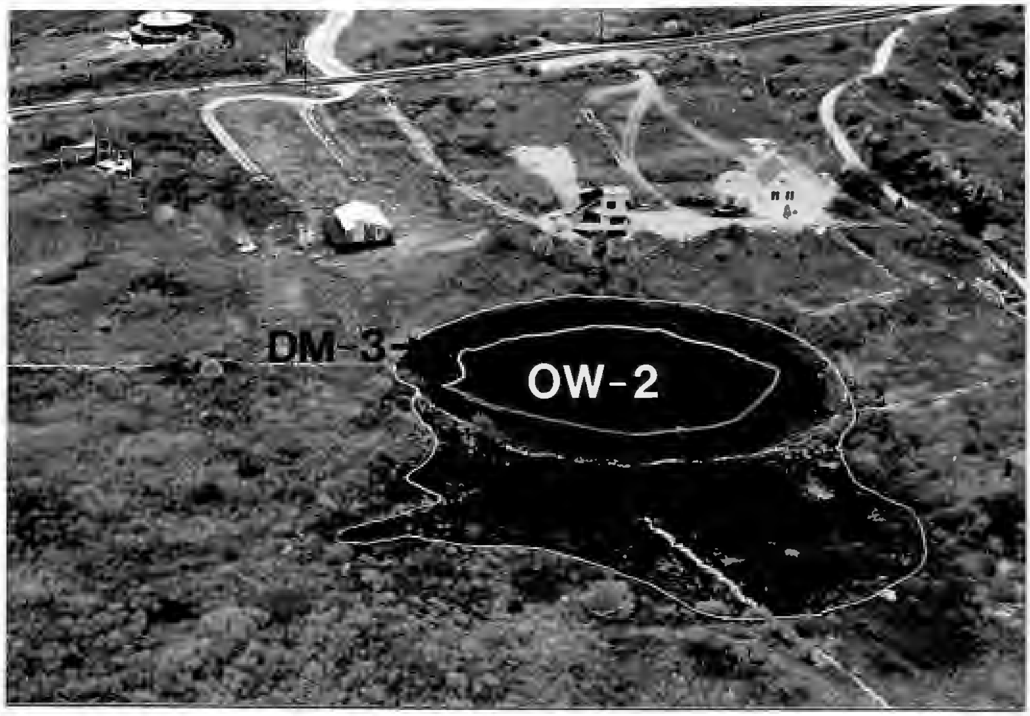

150
OW-2
146

Fig. 9.--Sub-shrub deep marsh (DM-3). Water willow (<u>Decodon verticillatus</u>) makes up the peripheral band of DM-3 surrounding nonvegetatated open water (OW-2). Aerial view looking northeast at wetland #113.

Fig. 10.--Robust deep marsh (DM-4). View looking southwest across Franklin Swamp (#84). Dominant vegetation of this subclass and this wetland is cattail (<u>Typha</u> spp.)


DM-3
OW-2


DM-4

dominate DM-4 on Block Island. The DM-4 in Franklin Swamp (#84) consists entirely of cattail (Fig. 11) while that in New Meadow Hill Swamp contains both cattails and reeds. Robust deep marsh is the second largest wetland subclass on Block Island.

Narrow-leaved deep marsh (DM-5): Narrow-leaved marsh emergents such as bur-reed (Sparganium spp.) and spikerush (Eleocharis spp.) are the characteristic vegetation. Examples of this subclass are wetlands at the end of Gracies Cove Road (Fig. 12) and East Great Swamp (#184).

Shallow Marsh (SM).-- Robust and marsh emergents are the dominant vegetation of this wetland class. The subclasses of shallow marsh are similar to those of deep marsh but water depth is less than 15 cm during the growing season. Two subclasses are present on Block Island.

Robust shallow marsh (SM-1): Cattail is the dominant vegetation. Robust shallow marsh has approximately two-thirds the areal extent of its deep marsh counterpart but is composed of almost twice as many individual wetlands. Small wetlands consisting entirely of SM-1 (#179-181,192-197,199) are especially concentrated within the residential center immediately west of Old Harbor. Ambrose Swamp (#170, Figs. 3,13) is an example of a larger wetland containing robust shallow marsh.

Narrow-leaved shallow marsh (SM-2): Bur-reed, spikerush and soft rush (Juncus effusus) are characteristic vegetation

Fig. 11.--Narrow-leaved deep marsh (DM-5). Northward view across small wetland (#70) near Gracies Cove Road. Spikerush (Eleocharis spp.) in foreground is an example of vegetation occurring in this subclass.

Fig. 12.—Robust shallow marsh (SM-1). Southward view along main axis of Ambrose Swamp (#170). Cattail (Typha latifolia) is the dominant vegetation of SM-1. Bushy shrub swamp (SS-2) is present along the east edge of the wetland.


DM-5


SS-2
SM-1

of SM-2. A small wetland (#149) immediately southeast of Payne Pond exemplifies narrow-leaved shallow marsh (Fig. 14).

Meadow (M).-- Meadow emergents are the characteristic vegetation. Surfaces of meadows may be devoid of water during the growing season but the soil is saturated. Throughout the rest of the year water depth may reach 15 cm. Three small meadows (#43, 162, 167) are present on Block Island. All are ungrazed meadows (M-1) dominated by rushes (Juncus spp.) and sedges (Carex spp.) (Fig. 15).

Shrub Swamp (SS).-- Shrubs are the dominant life-form of this class. Up to 30 cm of surface water is present seasonally or permanently. Two subclasses are present on Block Island.

Bushy shrub swamp (SS-2): Common shrubs include: highbush blueberry (Vaccinium corymbosum), speckled alder (Alnus rugosa), viburnum (Viburnum spp.) and sweet-pepper bush (Clethera alnifolia). The West Great Swamp (#185, Figs. 3,16) and the eastern edge of Ambrose Swamp (#170) are extensive examples of SS-2.

Aquatic shrub swamp (SS-4): The aquatic shrub, buttonbush (Cephalanthus occidentalis), is the dominant vegetation. Surface water tends to be deeper and less intermittent than in other subclasses of shrub swamp. Only one example of SS-4 occurs on the island (#147, Fig. 3,16).

Fig. 13.—Narrow-leaved shallow marsh (SM-2). West view across a small wetland (#149) southeast of Paynes Pond. Soft rush (Juncus effusus) in center of photo and sedges are characteristic vegetation. SM-2 is distinguished from its deep marsh counterpart (DM-5) by having less than 15 cm of surface water during the growing season.

Fig. 14.—Ungrazed meadow (M-1). West view across small wetland (#167) along Southeast Road. Rushes, sedges and Joe-pye weed (Eupatorium dubium) are characteristic vegetation of this subclass. Surface water is usually absent during the growing season but the soil is saturated.


SM-2


M-1

Fig. 15.—Bushy shrub swamp (SS-2). View is looking northeast along traverse line 6I of West Great Swamp (#185). Shrubs consist of speckled alder (Alnus rugosa), highbush blueberry (Vaccinium corymbosum), sweet-pepper bush (Clethra alnifolia) and swamp azalea (Rhododendron viscosum).

Fig. 16.—Aquatic shrub swamp (SS-4). Eastward view across the solitary wetland (#147) containing SS-4. Aquatic shrub is buttonbush (Cephalanthus occidentalis) and surrounds a small area of vegetated open water (OW-1).


SS-2


SS-4

Fen (F).-- Fens are characterized by a quaking substrate composed of poorly decomposed plant remains and a water table that lies at or slightly above the surface throughout the year. Sphagnum moss is scarce or absent entirely.

Emergent fen (F-1) is the only subclass present on the island (Fig. 17). Short meadow emergents including beak-rush (Rhynchospora spp.), cottongrass (Eriophorum spp.) and twig-rush (Cladium spp.) are the characteristic subforms of vegetation in emergent fens.

Bog (BG).-- Bogs have the floating or quaking mat of fens but the entire surface is carpeted with Sphagnum moss. Surface water is rarely seen in bogs, but the water table lies at or slightly below the surface throughout the year. Emergent and shrub life-forms of vegetation are present in the two subclasses of bog on Block Island.

Emergent bog (BG-1): Vegetation consists of cranberries (Vaccinium oxycoccos) and the sedges found in emergent fens. Figure 18 is one of two wetlands on Block Island containing BG-1. Both (#90,96) occur on the southwest side of the island in the vicinity of Cooneymus Road.

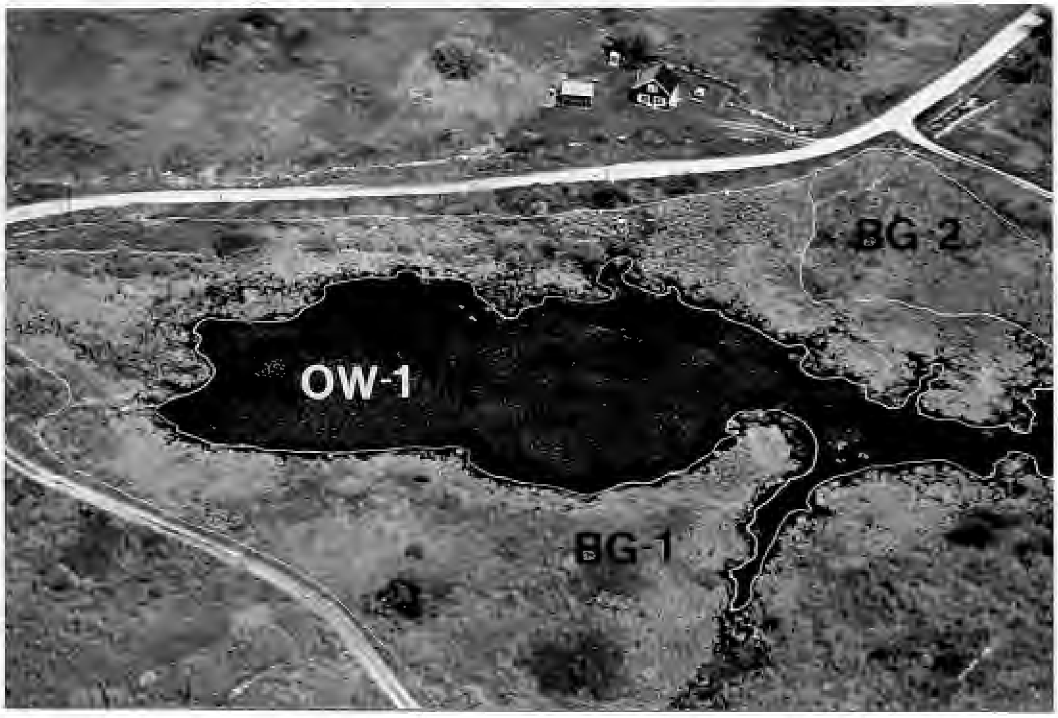
Shrub bog (BG-2): Sheep laurel (Kalmia angustifolia), swamp azalea (Rhododendron viscosum) and sweet gale (Myrica gale) are the low compact shrubs present in the shrub subclass. Leatherleaf (Chamaedaphne calyculata), a low compact shrub that commonly defines this subclass, is not abundant. Fresh Swamp (#126 Fig. 3,19) exemplifies this

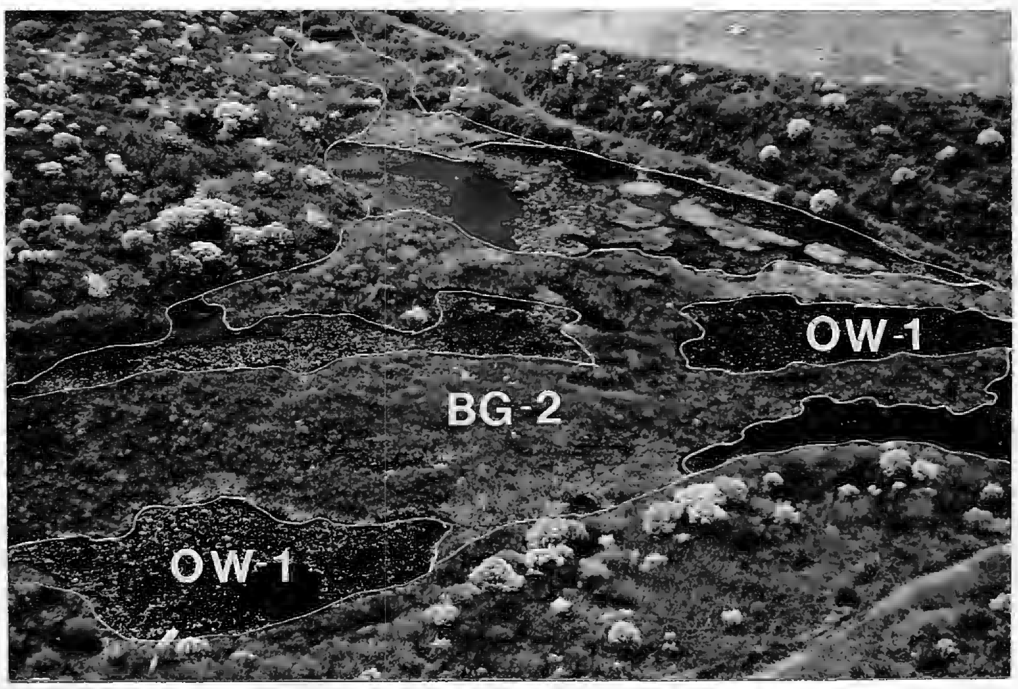
Fig. 17.—Emergent fen (F-1). Northwest view of wetland (#132) at corner of Lakeside Drive and Mohegan Trail. Vegetation includes cattail (*Typha angustifolia*), soft rush (*Juncus effusus*), cottongrass (*Eriophorum* spp.) and iris (*Iris versicolor*). Photograph courtesy of F. C. Golet.


F-1

Fig. 18.—Emergent bog (BG-1). Eastward aerial view of emergent bog surrounding vegetated open water (OW-1) in wetland #90. The quaking surface of the bog is covered by *Sphagnum* moss, beak rush (*Rhynchospora* spp.), cottongrass (*Eriophorum* spp.) and the insectivorous sundew (*Drosera* spp.). Shrub bog (BG-2) is present at the upper-right.

Fig. 19.—Shrub bog (BG-2). Aerial view of Fresh Swamp (#126) looking west. Sweet gale (*Myrica gale*), sheep laurel (*Kalmia angustifolia*), swamp azalea (*Rhododendron viscosum*) and water willow (*Decodon verticillatus*) are growing on a floating mat carpeted by *Sphagnum* moss and cranberry (*Vaccinium macrocarpon*).

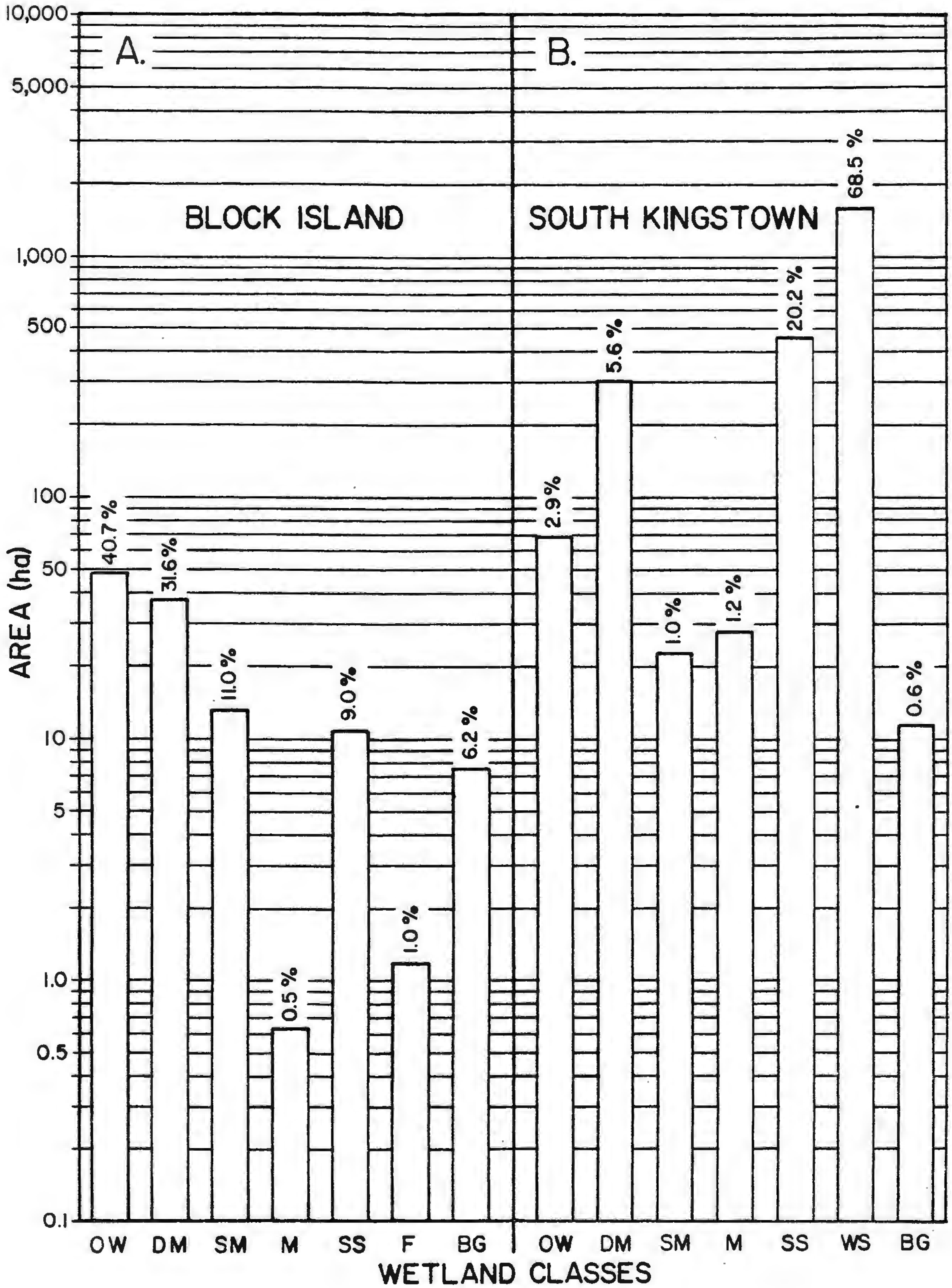

BG-2
OW-1
BG-1


OW-1
BG-2
OW-1

subclass.

The dominant wetland class on Block Island is open water (OW). Wooded swamp does not exist here (Fig. 20A) although it is the dominant wetland type throughout southern New England (Golet and Parkhurst, 1981). Twenty five km to the north in South Kingstown, Rhode Island (Fig. 20B), wooded swamp (WS) is the most abundant wetland class (Parkhurst, 1977). Peat harvesting on Block Island between 1721 and 1875 (Jackson, 1840; Livermore, 1961) may explain the absence of wooded swamp. In 1721 colonists of the island resorted to peat for fuel when the island's timber sources were depleted. These conditions would have been responsible for: 1) reduction of the seed source of wetland trees and 2) retrogression of wetland succession to the open water or pond stage. Other conditions prohibiting forest development seem unlikely as pre-1721 records indicate the presence of dense woods consisting of elm, oak, pine and cedar (Livermore, 1961).

Fig. 20.—Relative abundance of freshwater wetland classes from Block Island (3.7 km^2) and South Kingstown (158.9 km^2), Rhode Island. Total area of wetland on Block Island is 121.25 ha and total wetland area of South Kingstown is 2324.4 ha. South Kingstown data from Parkhurst (1977) in which fen is not recognized as a separate wetland class.



A.
B.
BLOCK ISLAND
SOUTH KINGSTOWN
AREA (ha)
10,000
5,000
1,000
500
100
50
10
5
1.0
0.5
0.1
40.7%
31.6%
11.0%
0.5%
9.0%
1.0%
6.2%
2.9%
5.6%
1.0%
1.2%
20.2%
68.5%
0.6%
OW DM SM M SS F BG
OW DM SM M SS WS BG
WETLAND CLASSES

Investigated Wetlands

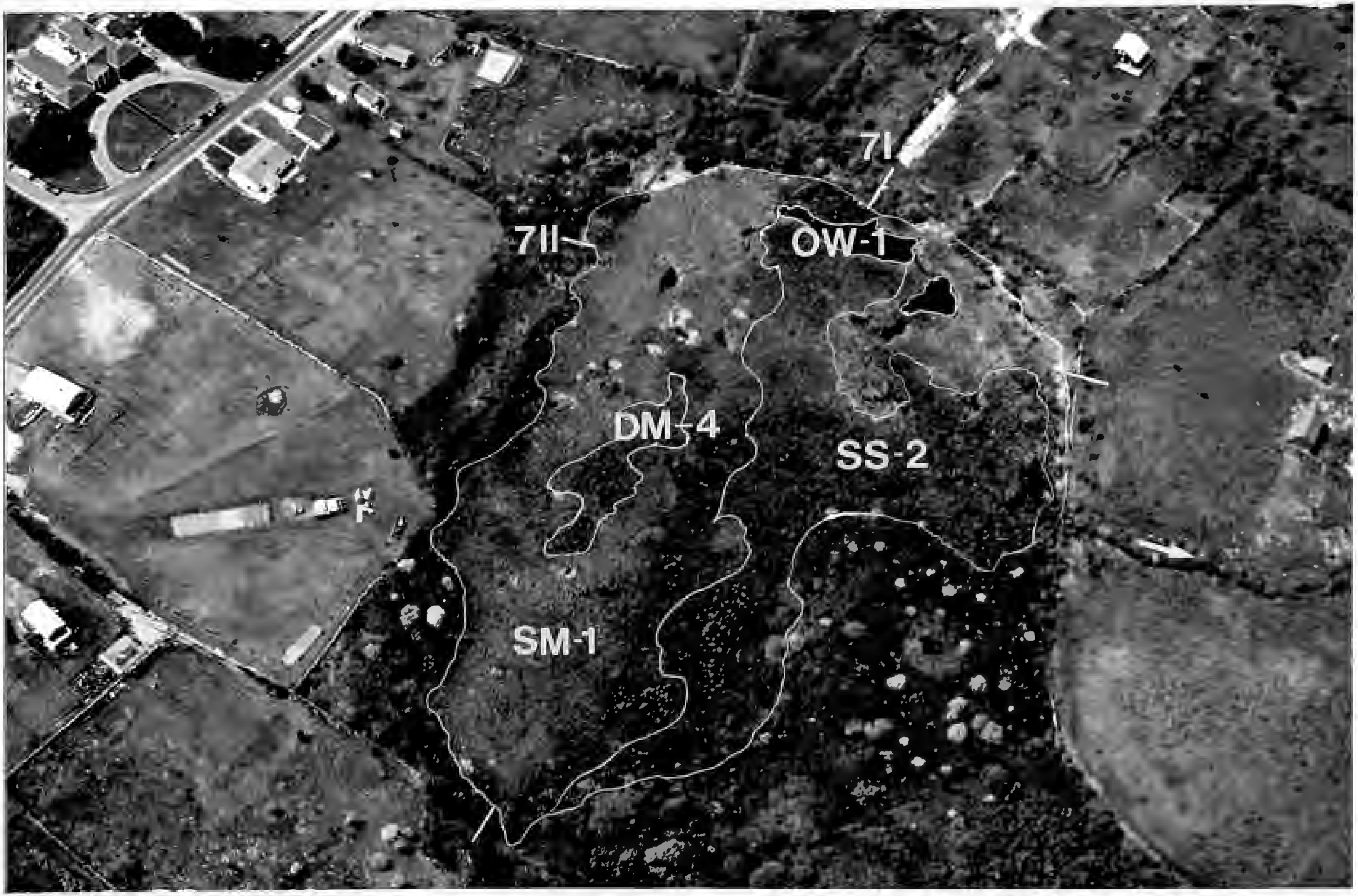
A description of the wetland types and peat stratigraphy in Ambrose, Franklin, Great and New Meadow Hill Swamps requires wetland maps (A), depth contour maps (B), peat isopach maps (C), and cross sections which appear in the back pocket as Figures 22, 23, 25, 27 and 29. Probe sites, core sites and traverse lines are indicated on all maps. Refer to Appendix 2A-L for detailed core logs and Appendix 3A-D for the peat volume of individual study areas.

Ambrose Swamp.-- Ambrose Swamp is located due east of High Street and the Block Island School (#170, Figs. 3, 21). The wetland is 230 m long by 180 m at the widest point and covers 2.6 ha (App. 1). Ambrose lies in an area of numerous upper perched water bodies (Fig. 4). A small brook drains eastward from the northeast edge of the wetland.

Four wetland subclasses are present (Figs. 21, 22A). Robust shallow marsh (SM-1) comprises 56% of the wetland. Bushy shrub swamp (SS-2) fringes the east edge and extends into SM-1. Subordinate areas of robust deep marsh (DM-4) and vegetated open water (OW-1) are present.

Six cores were taken along traverse lines 7I and 7II (Fig. 22B). Analyzed core 7IA marks the intersection of the two traverse lines. The location of analyzed cores in the other wetlands will be indicated but description of the analysis results will be discussed in the next section.

Fig. 21.--Aerial view of Ambrose Swamp (#170). North to top of photo, Block Island School top-left. Four wetland subclasses are present: robust shallow marsh (SM-1), bushy shrub swamp (SS-2), robust deep marsh (DM-4) and vegetated open water (OW-1). Outlet stream indicated by arrow. 7I and 7II are core traverse lines.


7I
7II
OW-1
DM-4
SS-2
SM-1

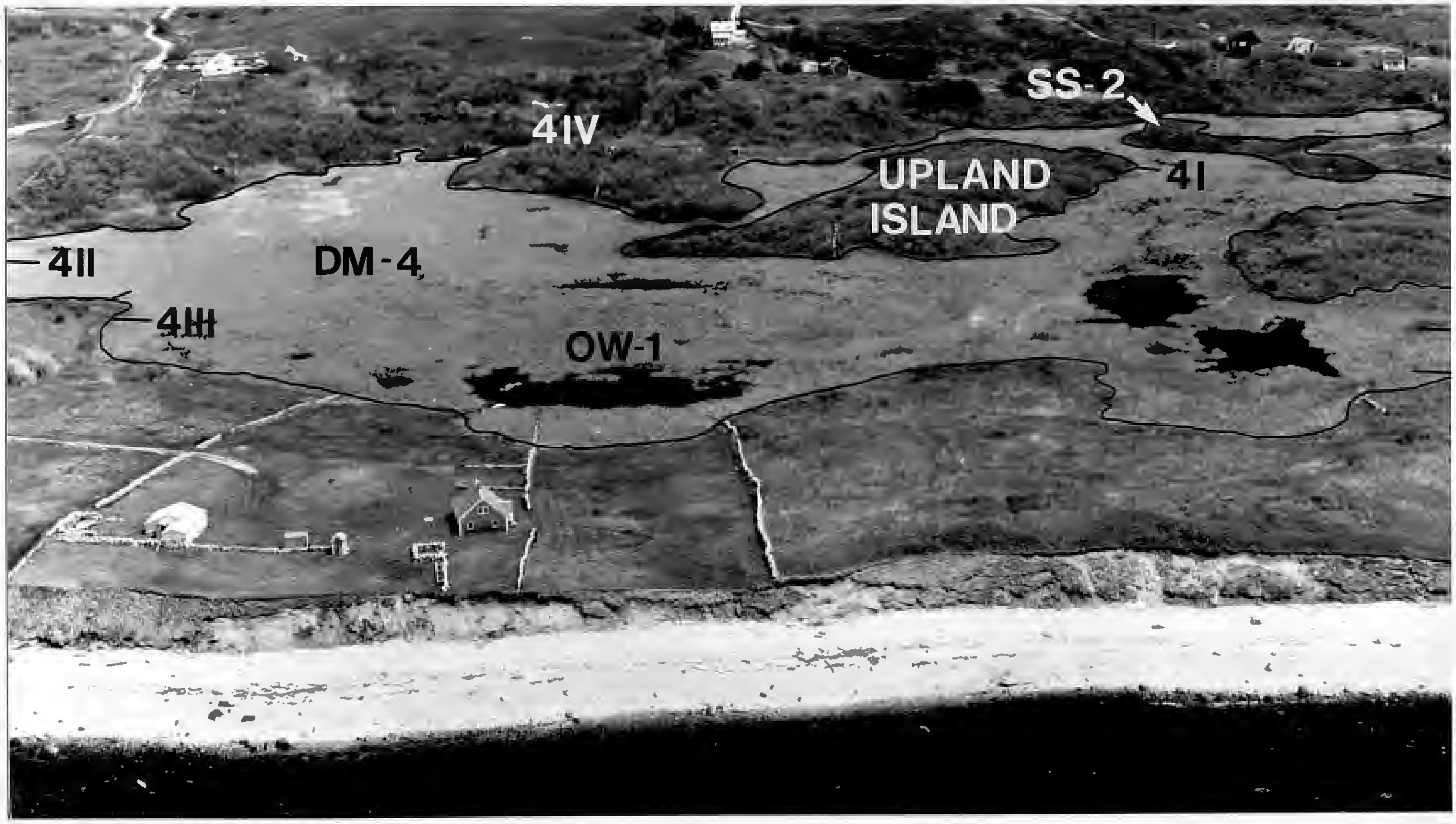
The surface of Ambrose Swamp is cohesive enough to bear the weight of people but high moisture content immediately below the root zone prohibits core recovery. The 100-300 cm zone of no recovery (NR) is present at the top of all cores (App. 2A). Excluding shallow core 7ID, 40-180 cm of moss peat containing wood fragments overlies 110-450 cm of reed-sedge. Woody material often extends into the upper portion of reed-sedge. Sedimentary peat, 20-200 cm thick, grading into silty peat is present at the base of all cores except 7IC and 7ID. Clay underlies the peat in all cores except 7ID which terminates in fine sand. Cross sections of both traverse lines appear in Figure 23. Peat stratigraphy is generalized between core sites because probe sites only reflect peat depth and not peat type.

Ambrose is the deepest of the seven investigated wetlands. The deepest core, 7IB (Fig. 22B), is near the center of the northwest-trending basin. The peat isopach map (Fig. 22C) reflects the deep, laterally continous zone of no recovery. However, at least 9 m of peat is present in the central part of the wetland.

Ambrose Swamp contains 69,150 m³ of peat, 57% of which lies below the 200 cm isopach contour (Fig. 22C). Refer to Appendix 3A for volumes of individual thickness intervals.

Franklin Swamp.-- Franklin Swamp is located on the west side of Block Island approximately 200 m south of Dories Cove Road (#84, Figs. 3,24). The irregularly shaped wetland is

Fig. 24. -- Eastward aerial view of Franklin Swamp (#34), the largest (7.89 ha) wetland on Block Island. An almost continuous stand of cattail (DM-4) dominates the surface. Other wetland subclasses include vegetated open water (OW-1) and bushy shrub swamp (SS-2). An island and upland necks divide the subsurface of the wetland into five separate basins (refer to Fig. 25B). 4I, 4II, 4III and 4IV are core traverse lines.


SS-2
4IV
UPLAND
ISLAND
4I
4II
DM-4
4III
OW-1

the largest on the island (7.89 ha) and measures 430 m north-south by 180 m east-west.

Franklin Swamp is located in the lower perched water zone (Fig. 4). Springs and intermittent drainage from a small wetland (#81) flow into Franklin Swamp along the north edge (Fig. 25A). Water ultimately flows south through smaller wetlands into Coonimus Swamp (#88 Fig. 3).

Robust deep marsh covers 78% of the wetland. Small areas of vegetated open water (OW-1) and bushy shrub swamp (SS-2) also exist (Figs. 24, 25A). A 0.81 ha upland island trends northwest along the east-central edge of the wetland.

A large northeast-trending basin lies beneath the main body of Franklin Swamp (Fig. 25B). Four smaller basins occur as outlying appendages. Ten cores were taken along traverse lines 4I-4IV. Core 4IIC was selected for fuel analysis. Core logs appear in Appendix 2B-D.

At the top of all cores is a 75-125 cm zone of no recovery. A reed-sedge and sedimentary peat sequence appears twice in cores from the 8 m deep main basin. In the upper sequence, 150-200 cm of reed-sedge overlies 200 cm of sedimentary peat. The sandy reed-sedge at the top of the lower sequence is 50-100 cm thick and overlies 150-200 cm of basal, silty-sedimentary peat. Cores in outlying appendages contain the reed-sedge and sedimentary peat of the upper sequence. Cross sections of the four traverse lines appear in Figure 23. Core 4IIB marks the intersection of lines 4II and 4IV.

Peat thickness in Franklin Swamp (Fig. 25C) is less affected by the zone of no recovery than in Ambrose Swamp (Fig. 22C). Up to 7 m of peat is present in the main basin. Except for the small basin in the northeast corner of the wetland, little peat occurs in the other small outlying basins.

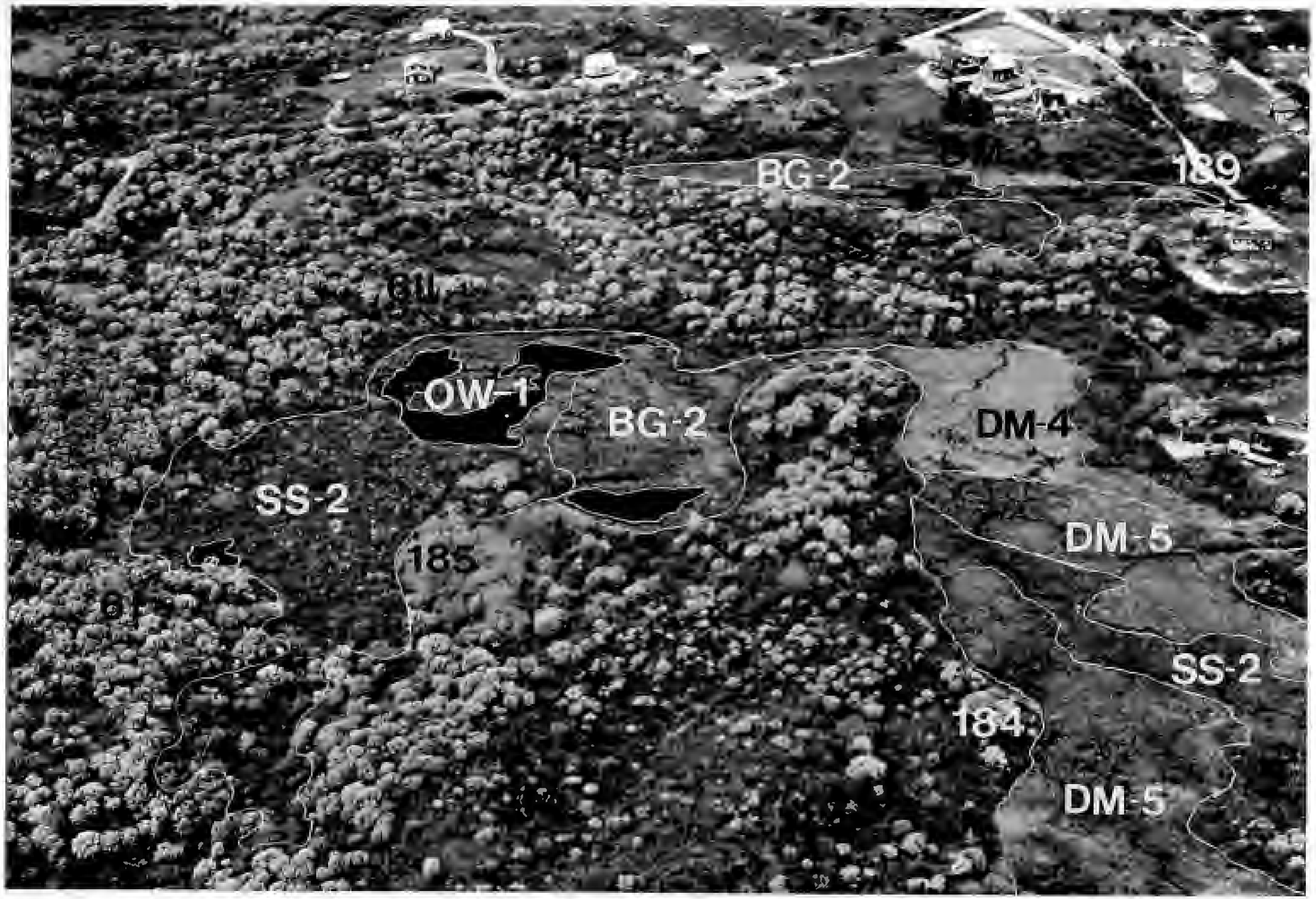
Franklin Swamp has 135,500 m^3 of peat. Peat thickness exceeding 1 m occurs in the main and northeast basins and constitutes 76% of the total volume. Refer to Appendix 3B for volumes of individual thickness intervals.

Great Swamp.-- Great Swamp is located southeast of the Block Island State Airport (Fig. 3). Upland necks and surface drainage divide Great Swamp into three separate segments (Figs. 26,27A). East Great Swamp (#184) is 310 m long north-south by 110 m east-west and covers 2.1 ha. The 1.8 ha West Great Swamp (#185) measures 220 m north-south by 140 m east-west. The Neptune Segment (#179) measures 210 m east-west by 50 m north-south and covers 0.9 ha. Total surface area of the Great Swamp is 4.79 ha (App. 1).

The entire Great Swamp lies within the lower perched water zone (Fig. 4). The Neptune Segment receives surface water from West and East Great Swamp and then drains into Mill Tail Swamp (Fig. 27A). East Great Swamp exhibits a deranged network of surface drainage.

East Great Swamp: Narrow-leaved deep marsh (DM-5) is the dominant wetland subclass (Fig. 27A). Bushy shrub swamp

Fig. 26.--Aerial view looking northeast at the three parts of the Great Swamp: East (#184), West (#185) and the Neptune Segment (#189). A total of six wetland subclasses are present: bushy shrub swamp (SS-2), vegetated open water (OW-1), shrub bog (BG-2), sub-shrub deep marsh (DM-3), robust deep marsh (DM-4) and narrow-leaved deep marsh (DM-5). Core traverse lines of East Great Swamp and the Neptune Segment are 5I and 2I respectively. 6I and 6II are traverse lines of West Great Swamp.


BG-2
189
OW-1
BG-2
DM-4
SS-2
185
DM-5
SS-2
184
DM-5

(SS-2) aligns the drainage network and also occurs along the southwest edge of the wetland. Robust deep marsh (DM-4) is present at the north end of East Great Swamp.

Five cores were taken along traverse line 5I (Fig. 27B). A sixth core is located 25 m east of 5IC. The deepest core, 5ID, was chosen for fuel analysis. Refer to Appendix 2H for core logs.

At the top of all cores is 15-65 cm of no recovery, underlain by less than 200 cm of sandy reed-sedge. Silty sedimentary peat, overlying fine sand is present at the base of the 2 deepest cores (5IC1, 5ID). A cross section of traverse line 5I appears in Figure 23.

The elongate, sinuous basin trends north and has a peat volume of 23,250 m^3 (App. 3C). Maximum peat thickness is approximately 3 m (Fig. 27C).

West Great Swamp: Bushy shrub swamp (SS-2) is dominant and occurs on the west side of the wetland (Fig. 27A). The east side consists of shrub bog (BG-2). Vegetated open water (OW-1) is concentrated at the north-central end of the wetland with isolated pools occurring at the south ends of SS-2 and BG-2.

A shallow northwest-trending ridge divides West Great Swamp into northeast and southwest basins (Fig. 27B). Five cores were taken along traverse lines 6I and 6II. Two additional cores (6D, 6E) are located east and west of the traverse lines intersection. Core 6IIA was selected for fuel analysis because of the meter-long intervals of three different peat types (App. 2F).

Excluding cores 6E and 6IIB, the 50-75 cm zone of no recovery is underlain by interbedded reed-sedge and woody moss peat (App. 2F,G). Sedimentary peat overlies fine sand at the bottom of cores 6IIA,B and 6IC. Sandy reed-sedge overlying fine sand is the basal unit of the other four cores. Cross sections (Fig. 23) illustrate the complex peat stratigraphy.

The peat volume of West Great Swamp is 37,030 m³ (App. 3C). Maximum peat thickness for the northeast and southwest basins is 5 and 3 m respectively (Fig. 27C).

Neptune Segment: Three wetland subclasses are present in the Neptune Segment (Fig. 27A). Shrub bog (BG-2) is confined to the west end of the wetland and covers 49% of the total area. Bushy shrub swamp (SS-2) occurs along the south-central edge of the wetland where nutrient-rich water enters from the East Great Swamp. The east third of the wetland is sub-shrub deep marsh (DM-3) consisting of Decodon.

Five cores were taken along traverse line 2I (Fig. 27A) with core 2ID selected for fuel analysis. Only two cores were taken and one probe made in the DM-3 because the surface would not support people and the density of Decodon prevents work from a skiff. Core logs appear in Appendix 2H.

A 50-200 cm zone of no recovery is present at the top of all cores and is thickest under the bog's floating mat.

Beneath no recovery, 50-100 cm of reed-sedge overlies 25-50 cm of sedimentary peat that grades into silt. This upper reed-sedge unit is absent in core 2IB. At the base of all cores, 25-125 cm of sandy reed-sedge peat overlies coarse sand. A complete sequence is not present in core 2IA because of its shallow depth.

A cross section of traverse line 2I appears in Figure 23. The wetland is not divided into two basins as is indicated in cross-sectional view. The ridge between cores 2IB and 2IC results from the traverse line passing over a low promontory that extends beneath the north-central edge of the wetland (Fig. 27B).

The deep zone of no recovery reduces peat thickness (Fig. 27C) to 50% of the wetland depth (Fig. 27B). Total peat volume is 8,000 m³ (App. 3C).

New Meadow Hill Swamp: New Meadow Hill Swamp is located on east-central Block Island and borders the Block Island Power Company on 3 sides (Fig. 28). The wetland is bounded by Ocean Road on the northeast and Beach Avenue on the northwest (#204, 205, Fig. 3). Although surficially contiguous, New Meadow Hill Swamp is artificially divided into west and east segments near core 3IIIC where the wetland is 13 m wide (Fig. 29A). For simplicity, the boundary is placed along the OW-2/DM-4 edge. The west segment (#205) measures 380 m east-west by 160 m north-south

Fig. 28.--East (#204) and West (#205) New Meadow Hill Swamp border the Block Island Power Company on three sides. View is to the northwest with Trims Pond at top-center. Tributary wetland (#203) is in foreground.

205
203
204

and covers 3.64 ha (App. 1). The east segment (#204) measures 180 m east-west by 150 m north-south and covers 2.14 ha (App. 1).

The entire New Meadow Hill Swamp lies within the lower perched water zone (Fig. 4). At the southwest end of the east segment, a small brook enters from a tributary wetland consisting of SS-2 (Fig. 29A). Surface water flows from the west segment into Trims Pond via a culvert north of core 3IE.

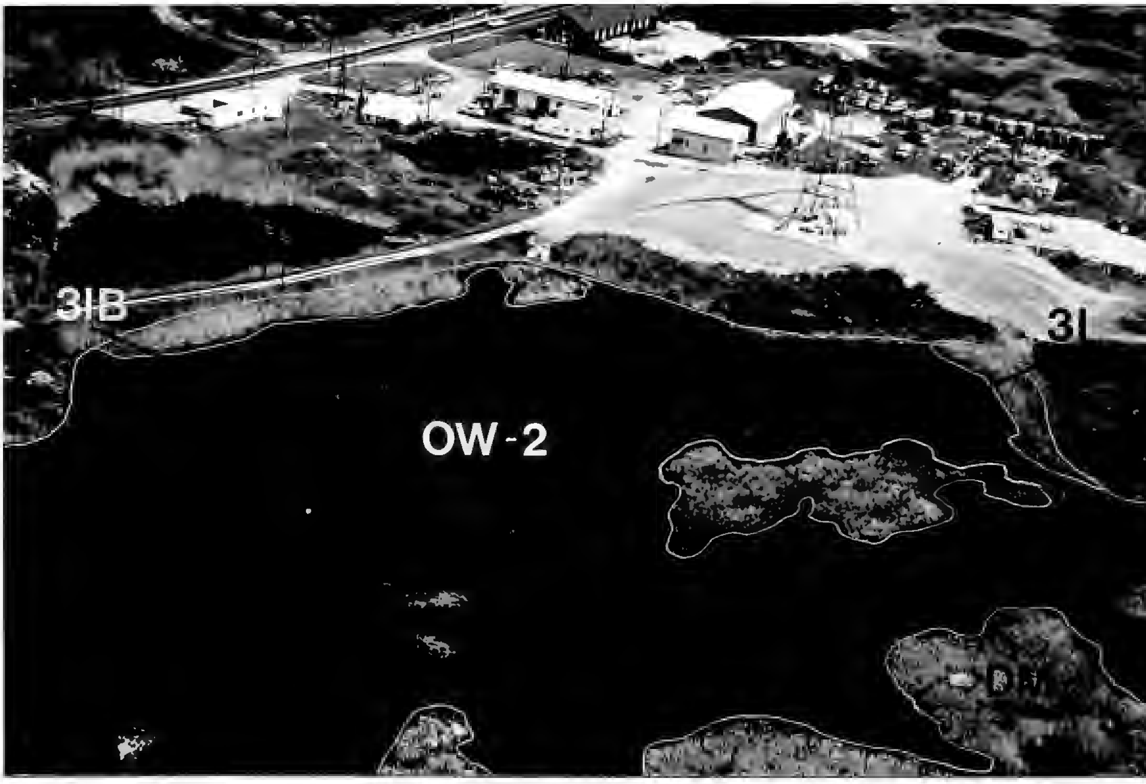
West Segment: Two wetland subclasses are present (Fig. 29A). Nonvegetated open water (OW-2) (Fig. 30) is dominant with robust deep marsh (DM-4) occurring along the edges and as floating islands. The buoyant surface of DM-4 is similar to the floating mat of bogs.

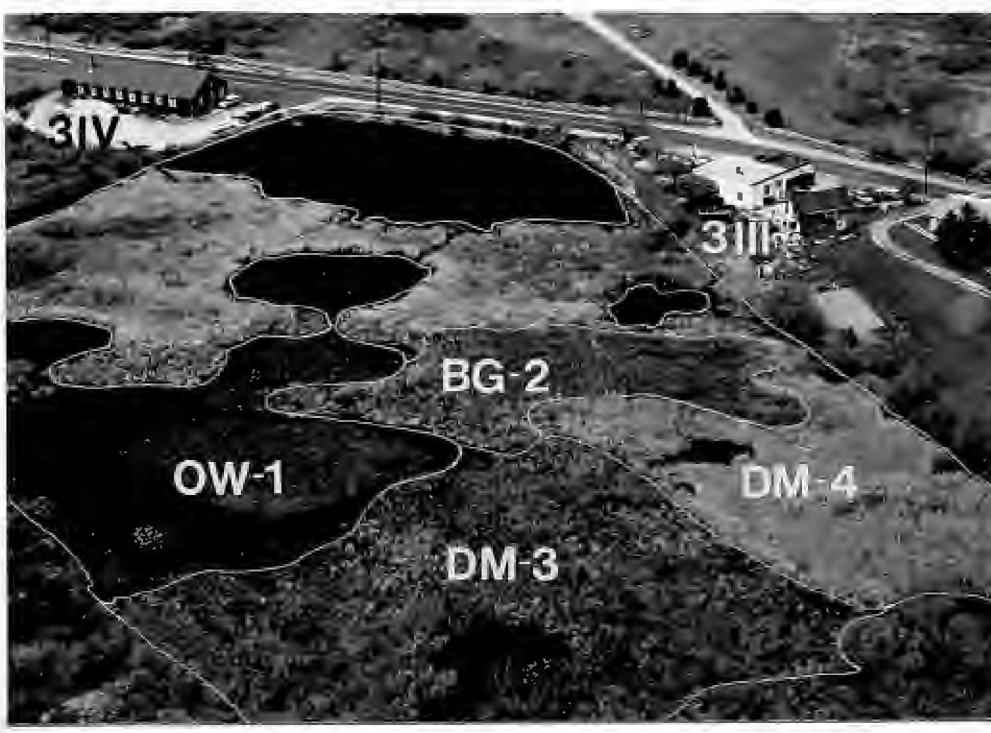
The west segment consists of an 11 m deep main basin and a smaller elongate basin positioned near the west-east segment boundary (Fig. 29B). Thirteen cores were taken along traverse lines 3I, 3IB and 3II. Cores 3IID and 3IIE are located in the west segment but occur on the southwest end of a traverse line (3III) that crosses both segments of New Meadow Hill Swamp. Core 3IB and 3IIB were selected for fuel analysis. Water depth and the unfirm substrate required most cores to be taken from a skiff. Core logs appear in Appendix 2I,J.

Water depth for the 5 cores taken in OW-2 is 75-135 cm and no recovery extends 40-140 cm below the water-substrate interface. The no recovery zone for cores in DM-4 is much

Fig. 30.--Northeast view of West New Meadow Hill Swamp. Islands of cattail (IM-4) are floating in nonvegetated open water (OW-2). 3I and 3IB are two of three traverse lines in this part of New Meadow Hill Swamp.

Fig. 31.--Northward view of East New Meadow Hill Swamp. Four wetland subclasses are present: vegetated open water (OW-1), robust deep marsh (IM-4), sub-shrub deep marsh (IM-3) and shrub bog (BG-2). 3III and 3IV are the two core traverse lines crossing this part of New Meadow Hill Swamp.


3IB
3I
OW-2


3IV
3III
BG-2
OW-1
DM-4
DM-3

thicker, ranging from 180-600 cm and even occurs within the reed-sedge layer in core 3IIE. Beneath no recovery, 300-495 cm of reed-seige occurs in the 8 cores exceeding 5 m in length (App. 2I,J). Sedimentary peat is thickest (200-300 cm) in the center of the main basin and thins towards the edges (Fig. 23). At the bottom of the deepest cores is silty peat and silt overlying fine sand. Shallow cores on the edge of the basin terminate in fine sand. Cores in the small, elongate basin consist of thinner (40-150 cm), sandy reed-sedge overlying 25-70 cm of silty, sedimentary peat. These cores also terminate in fine sand.

The zone of no recovery has a pronounced effect on peat thickness in the main basin of the west segment. Peat thickness (Fig. 29C) is approximately 50% of the basin depth (Fig. 29B). No recovery also isolates peat thickness exceeding 1 m in the small, elongate basin from the main basin (Fig. 29C). The west segment has a total peat volume of 78,440 m³ and contains 70% of the peat in the entire New Meadow Hill Swamp (App. 3D).

East Segment: The east segment exhibits greater subclass richness (Fig. 31) than the west segment. Robust deep marsh (DM-4) is dominant followed by sub-shrub deep marsh (DM-3). Vegetated open water (OW-1) occurs as interconnected pools along the center of the east segment and as isolated pools within other subclasses (Fig. 29A). Near the east-central edge of this segment, a small area of shrub bog (BG-2) lies amidst the the other three subclasses.

The east segment is an elongate, north-trending basin (Fig. 29B). Six cores were taken along traverse lines 3III and 3IV. Traverse line 3III extends into the west segment. A seventh core (3IVD) lies 35 m south of analyzed core 3IVC. All cores except 3IIIC, have 125-300 cm of no recovery (App. 2K,L). Core 3IIIC is located on a low rise near the east-west segment boundary and consists of 15 cm of reed-sedge terminating in fine sand.

The moss peat at the top of core 3IVB is 275 cm thick and overlies 50 cm layers of reed-sedge and sedimentary peat. At the top of adjacent core 3IVC, a meter of moss peat overlies an equal thickness of no recovery. No recovery in 3IVC and the lower no recovery zone in core 3IIIA are assumed to be lateral continuations of the moss peat layer in core 3IVB (Fig. 23). The high water content of fibrous, moss peat (Verry and Boelter, 1979), is considered to be responsible for no recovery in these particular cores.

The 50 cm of reed-sedge in core 3IVB is 50-210 cm thick in all other cores and lies above 25-200 cm of sedimentary peat. All cores terminate in fine sand (App. 2K,L).

Peat thickness in the east segment is less affected by no recovery than in the west segment (Figs. 29B,C). Peat volume of the east segment is 33,150 m³. The total peat volume of the entire New Meadow Hill Swamp is 111,590 m³ (App. 3D).

Fuel Analysis and Peat Resource

The Department of Energy, Coal Preparation Laboratory performed fuel analysis on 8 stratigraphically continuous cores that include: one each from Ambrose and Franklin Swamps, 3 from the Great Swamp (1 per segment) and 3 from New Meadow Hill Swamp. Cores were analyzed in 1 m sections. Refer to Appendix 4 for complete fuel analyses. The stratigraphic relationship of moisture free (MF) ash, heating value and sulfur appear in Figures 32-34.

The Ambrose Swamp core (7IA) is 572 cm long and contains 3 peat types (Fig. 32A). Ash increases with depth and ranges from 10.70 to 53.95% (MF weight). The highest BTU value occurs for moss peat (9136) and the lowest for sedimentary peat (4683). Sulfur content ranges from 0.62 to 0.98.

The Franklin Swamp core (4IIC) measures 680 cm and is the longest analyzed core. Two sequences of reed-sedge and sedimentary peat are present. Ash content ranges from 41.07 to 65.00% but does not progressively increase with depth (Fig. 32B). The BTU/lb values and sulfur content range from 3501 to 5926 and 0.36 to 1.04% respectively.

The 350 cm East Great Swamp core (5ID) consists of sandy reed-sedge and sedimentary peat (Fig. 33A). Two 25 cm sand layers contribute to the high ash content (73-88%). This core exhibits the lowest BTU values (887-2648) of all analyzed cores. Sulfur content ranges from 0.26 to 0.43%.

Fig. 32. — Moisture-free ash, BTU/lb and sulfur values of analyzed cores from Ambrose (7IA) and Franklin (4IIC) Swamps. Symbols for peat types are same as those in App. 2 and Fig. 23. Letters along right side of core log refer to analyzed core sections in App. 4.

〉 indicates core section containing fuel grade peat.

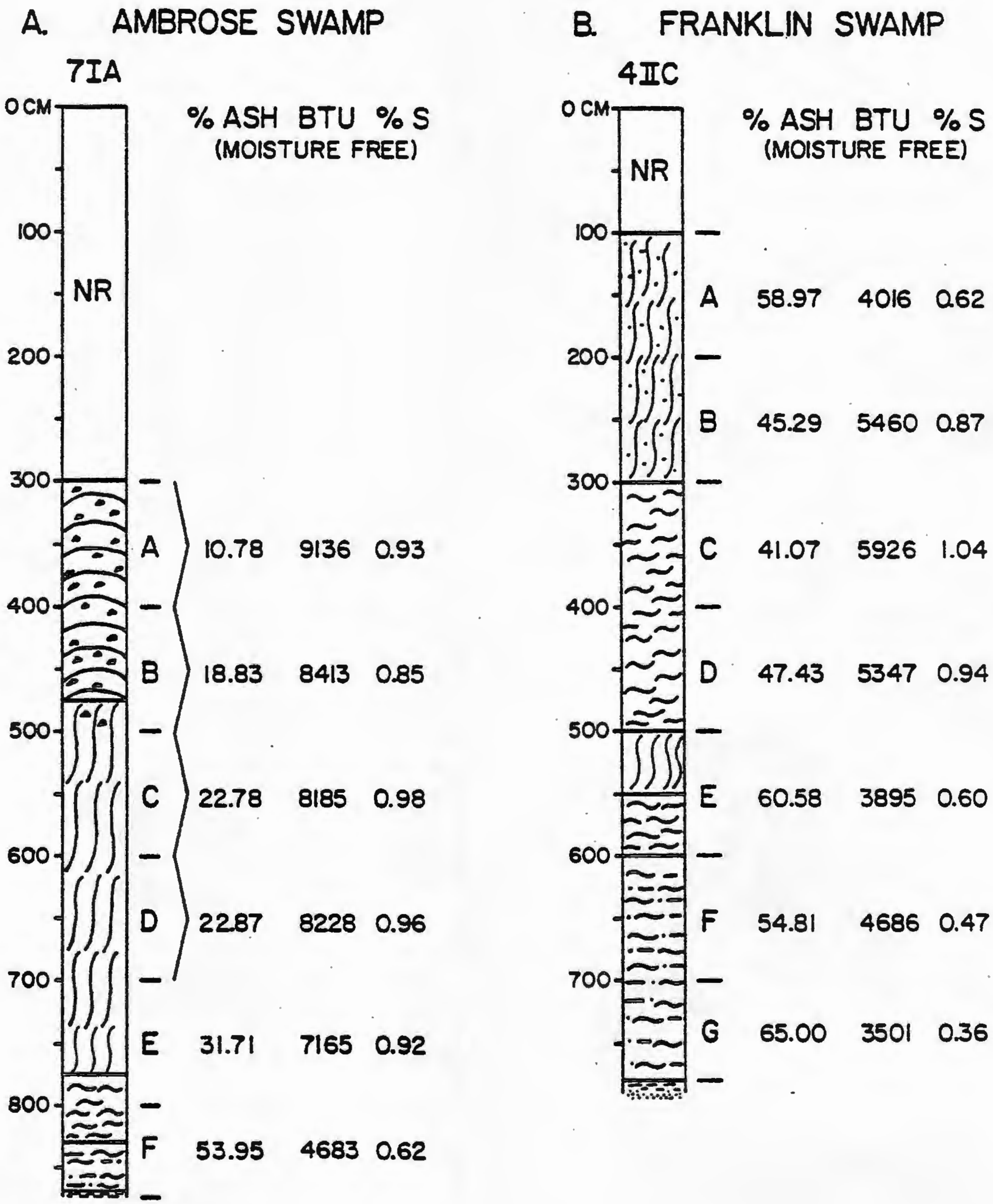
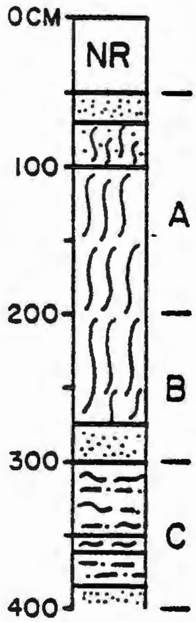

A. AMBROSE SWAMP
7IA
0 CM
100
200
300
400
500
600
700
800
NR
% ASH BTU % S
(MOISTURE FREE)
A 10.78 9136 0.93
B 18.83 8413 0.85
C 22.78 8185 0.98
D 22.87 8228 0.96
E 31.71 7165 0.92
F 53.95 4683 0.62
B. FRANKLIN SWAMP
4IIC
0 CM
100
200
300
400
500
600
700
NR
% ASH BTU % S
(MOISTURE FREE)
A 58.97 4016 0.62
B 45.29 5460 0.87
C 41.07 5926 1.04
D 47.43 5347 0.94
E 60.58 3895 0.60
F 54.81 4686 0.47
G 65.00 3501 0.36

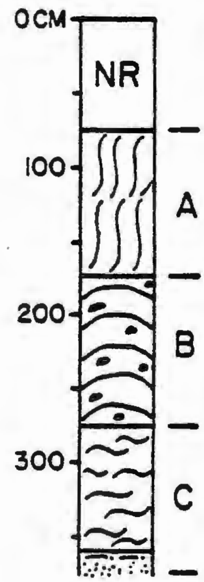
Fig. 33. — Moisture-free ash, BTU/lb and sulfur values of analyzed cores from East Great Swamp (5ID), West Great Swamp (6IIA) and the Neptune Segment (2ID).

A. E GREAT SWAMP



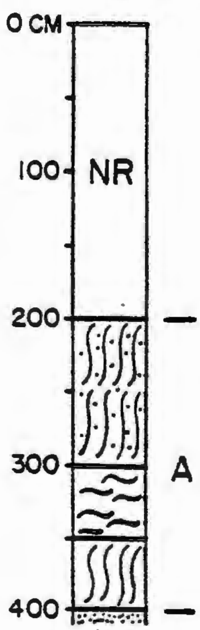
	% ASH	BTU	% S
	(MOISTURE FREE)		
A	73.18	2648	0.43
B	85.34	1151	0.34
C	87.35	887	0.26

B. W GREAT SWAMP



	% ASH	BTU	% S
	(MOISTURE FREE)		
A	17.48	8450	0.58
B	10.67	9169	0.76
C	82.36	1723	0.24

C. NEPTUNE SEGMENT



	% ASH	BTU	% S
	(MOISTURE FREE)		
A	61.27	3854	0.44

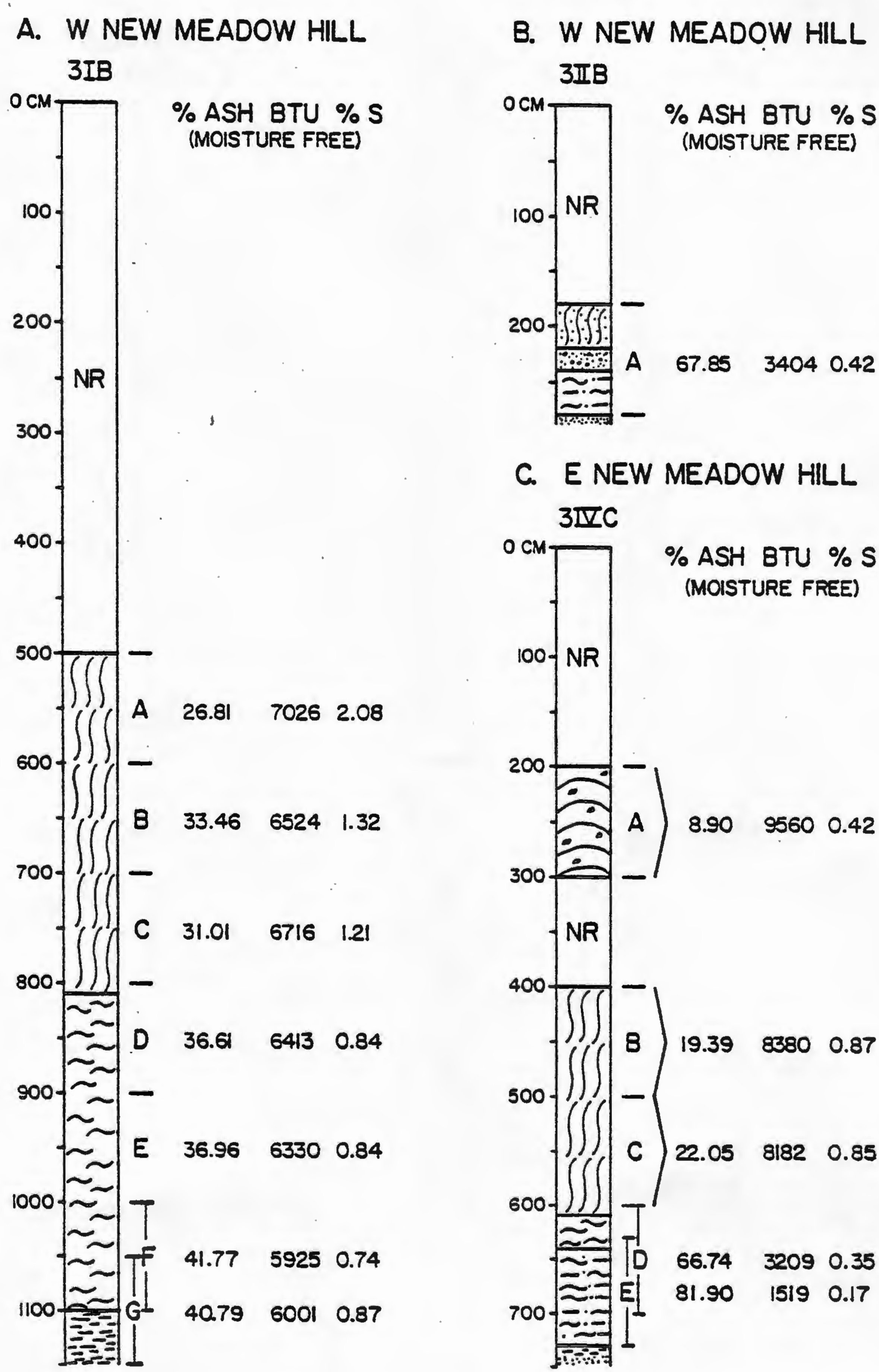
The analyzed core (6IIA) from the West Great Swamp contains meter-long intervals of reed-sedge, moss and sedimentary peat. The lowest ash content (10.67%) and highest BTU value (9169) occur in the moss interval with highest ash and lowest BTU values in the basal sedimentary peat (Fig. 33B). Sulfur content ranges from 0.24 to 0.76%.

The 2 m core from the Neptune Segment consists of sandy reed-sedge and sedimentary peat. One analysis was performed on the entire 2 m section. Ash content is 61.27% and BTU value is 3854 (Fig. 33C).

Two cores were analyzed in West New Meadow Hill Swamp. Core 3IB contains 3 m layers of reed-sedge and sedimentary peat. Lowest ash content (26.81-31.01%) and highest BTU values (6524-7026) occur in the reed-sedge (Fig. 34A). The basal sedimentary peat has ash and BTU ranges of 36.61 to 41.77% and 5925 to 6413 respectively. Sulfur ranges from 0.74 to 2.08%. The upper 3 m have the highest sulfur content of all analyzed cores. The proximity of 3IB to the Block Island Power Company is a possible explanation for the high sulfur values. Core 3IIB consists of sandy, reed-sedge and sedimentary peat which yield high ash content and low BTU values (Fig. 34B).

The analyzed core 3(IVC) from East New Meadow Hill Swamp measures 430 cm and contains three peat types. The moss peat at the top of this core has an ash content of 8.90% and a BTU value of 9560 (Fig. 34C) and has the highest fuel value of all analyzed cores. The underlying 2 m of

Fig. 34. -- Moisture-free ash, BTU/lb and sulfur values of analyzed cores from West (3IB, 3IIB) and East (3IVC) New Meadow Hill Swamps. High sulfur values in upper 3m of 3IB assumed to result from proximity of core to Block Island Power Company.


A. W NEW MEADOW HILL
3IB
% ASH BTU % S
(MOISTURE FREE)
0 CM
100
200
300
400
500
600
700
800
900
1000
1100
NR
A 26.81 7026 2.08
B 33.46 6524 1.32
C 31.01 6716 1.21
D 36.61 6413 0.84
E 36.96 6330 0.84
F 41.77 5925 0.74
G 40.79 6001 0.87
B. W NEW MEADOW HILL
3IIB
% ASH BTU % S
(MOISTURE FREE)
0 CM
100
200
NR
A 67.85 3404 0.42
C. E NEW MEADOW HILL
3IVC
% ASH BTU % S
(MOISTURE FREE)
0 CM
100
200
300
400
500
600
700
NR
A 8.90 9560 0.42
NR
B 19.39 8380 0.87
C 22.05 8182 0.85
D 66.74 3209 0.35
E 81.90 1519 0.17

reed-sedge has an ash content of 19.39 to 22.05% with BTU values ranging from 8182 to 8380. The basal sedimentary peat has high ash content and low BTU values. Sulfur ranges from 0.17 to 0.94% and decreases with depth.

Moisture-free peat types of Block Island are ranked in Table 3. Ash and BTU ranges of the different peat types are broad and overlap. Ash generally increases with depth but exceptions occur in Franklin and West Great Swamp (Figs. 32B, 33B). However, a linear relationship (99.5 significance level) does exist between ash and BTU/lb (Fig. 35).

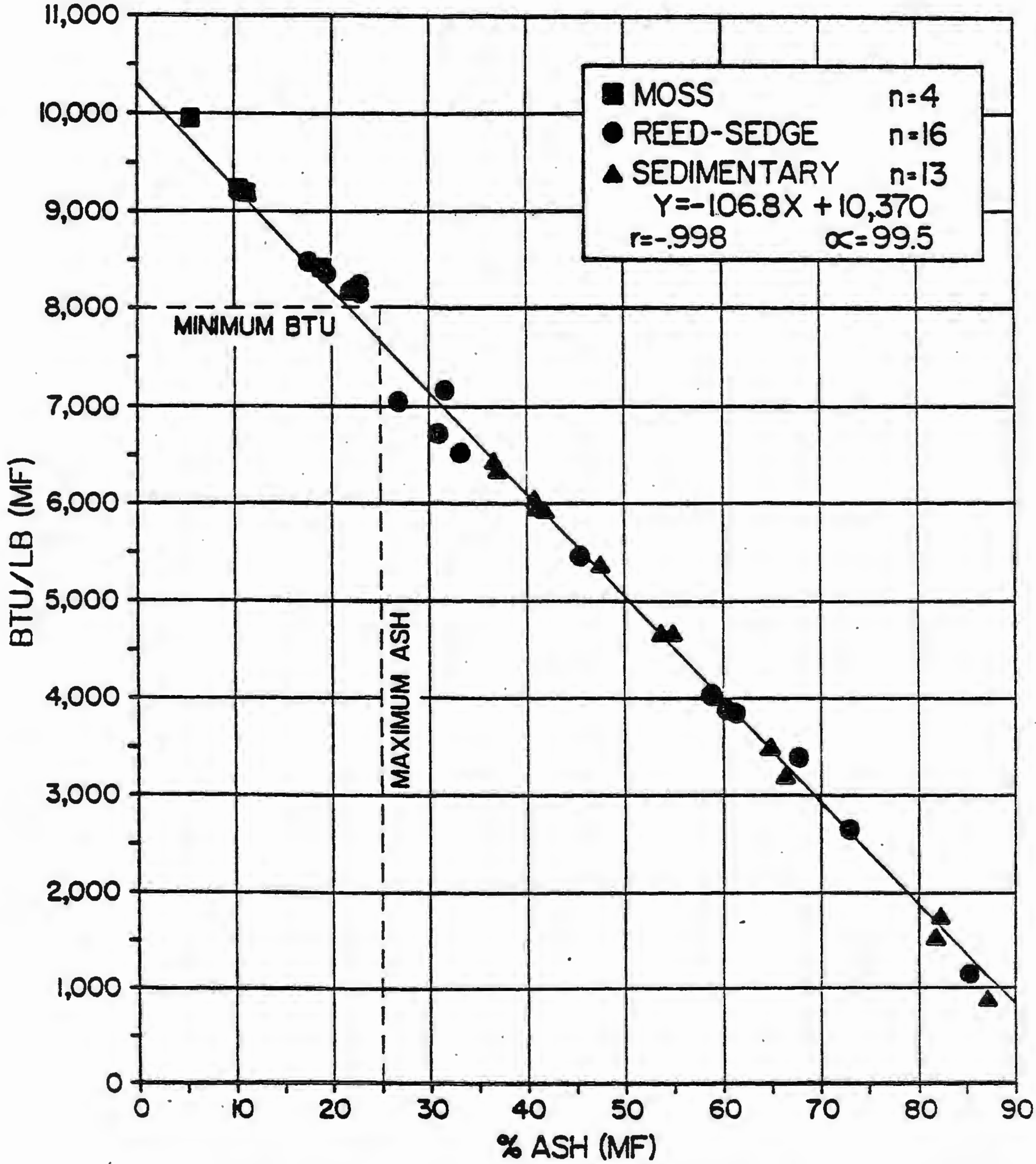
Table 3. Rank of peat types

	Peat Type	% Ash	BTU/lb	% Sulfur
1)	Moss	9-19	8400-9600	0.76-0.94
2)	Reed-sedge	17-34	6500-8500	0.58-2.08
3)	Sedimentary	36-54	4700-6400	0.62-1.04
4)	Sandy reed-sedge	45-85	1200-5500	0.37-0.87
5)	Silty sedimentary	55-87	900-3400	0.17-0.60

The fuel analyses (App. 4) indicate the cores contain 62-92% moisture. Moisture content exceeding 80% is probably more representative, as the peats below this level have high ash contents (>50%). Thus only 10-20% of the core volume is actually organic material and ash. Peat must be dewatered or air dried to approximately 35% moisture in order to be used as a fuel source. Peat density at this moisture content is 15 lb/ft^3 or 243 kg/m^3 (U.S. D.O.E., 1979).

Fig. 35.—Relationship of BTU/lb to ash in analyzed, moisture-free peat cores from Block Island, Rhode Island. Fuel-grade BTU and ash limitations defined by U.S. DOE (1980).

BTU vs ASH CONTENT



The metric tonnage (MT) of air dried peat is the product of isopach volume (App. 3) and peat density (0.24 MT/m^3) at 35% moisture. Isopach maps of the investigated wetlands indicate the zone of no recovery reduces peat thickness by 10-50% of wetland depth. High moisture content causes the peat to exist as a thick slurry and prevents retrieval by a Davis or gouge corer. Consequently, peat tonnages determined from isopach maps of the investigated wetlands are conservative. Subsequent use of a McCauley corer in comparable wetlands has reduced or eliminated core loss associated with no recovery.

The volume of the no recovery zone, excluding areas of open water (App. 1) which are assumed to have an average depth of 1 m, is equal to the difference in volume between depth contour and peat isopach maps. Air-dried tonnages of peat for each investigated wetland appearing in Table 4 are derived from both the peat isopach maps and the depth contour maps.

Fuel-grade peat exceeds 8,000 BTU/lb (MF), has less than 25% ash and occurs in deposits thicker than 4 ft (U.S. D.O.E., 1980). Peat meeting these requirements occurs in Ambrose, West Great, and East New Meadow Hill Swamps (Figs. 31-33). Analyzed core intervals immediately below the zone of no recovery for each of these wetlands have ash (8.90-17.48) and BTU values meeting fuel-grade criteria. Ash generally increases with depth; consequently, peat in the zones of no recovery is assumed to be of fuel quality

Table 4. - Air dried (35% moisture), metric tonnes of peat in investigated wetlands.

	Isopach volume(m^3)	Isopach metric tonnes	No Recovery volume (m^3)	No Recovery metric tonnes	Total metric tonnes
Ambrose Swamp	69,150	16,600	42,990	10,320	26,920
Franklin Swamp	135,500	32,500	32,040	7,690	40,190
East Great Swamp	23,250	5,580	6,590	1,580	7,160
West Great Swamp	37,030	8,900	6,000	1,440	10,340
Neptune Segment	8,000	1,920	7,660	1,820	3,740
West New Meadow Hill Swamp	78,440	18,800	33,030	7,900	26,700
East New Meadow Hill Swamp	33,150	7,950	18,960	4,550	12,500
	384,520 m^3	92,250 MT	147,270 m^3	35,300 MT	127,550 MT

Table 5. - Air dried, metric tonnes of fuel grade peat (> 8000 BTU/lb MF, < 25% ash).

	Isopach interval	Isopach volume (m^3)	Isopach metric tonnes	No Recovery metric tonnes	Total metric tonnes
Ambrose Swamp	1,2,3,4 (Fig. 22C)	54,150	13,000	10,320	23,320
West Great Swamp	1,2,3 (Fig. 27C)	31,130	7,470	1,440	8,910
East New Meadow Hill	1,2,3 (Fig. 29C)	28,700	6,890	4,550	11,440
West New Meadow Hill				7,900	7,900
		113,980 m^3	27,360 MT	24,210 MT	51,570 MT

and is included in the metric tonnage of fuel-grade peat for the three wetlands (Table 5). West New Meadow Hill Swamp is included in Table 5 because the uppermost ash (26.81) and BTU (7026) values are near fuel-grade.

DISCUSSION

The peat deposits of Block Island are contained within freshwater wetlands (Fig. 3). Furthermore, freshwater wetlands are recognized as areas of groundwater recharge, flood control, recreation and wildlife habitat (Rhode Island, 1971; Goodwin and Niering, 1974; Odum, 1979; Larson, 1976). Therefore, wetland mapping is essential to land use planning and wildlife habitat evaluation. Figure 3 and Appendix 1 provide a more comprehensive and detailed inventory of Block Island's freshwater wetlands than previous land use and vegetative cover inventories (Kupa and Whitman, 1972; MacConnell, 1974; RI CRMC, 1977).

During the National Wetlands Inventory (U.S. Dept. Interior, in prog.), the wetlands and deep water habitats of Block Island were classified using the Cowardin et al. (1979) system. However, a method of habitat evaluation has not yet been developed for this system. Consequently, state agencies such as the Department of Environmental Management use a wetland wildlife habitat evaluation which applies the Golet and Larson (1974) freshwater wetland classification system (C. Ariel - RI DEM, pers. comm., 5/27/81).

Succession in Block Island Wetlands

Identification of present vegetation communities from aerial photographs has been used as an indicator of the type and depth of peat occurring beneath the surface of wetlands (Young and Stoeckler, 1961 in Kennedy, 1963; Boch, 1965; Abramova, 1965; Yasmol'skaya, 1965) A uniform pattern of wetland succession is the underlying assumption of this technique. However, successional patterns are not always predictable (Gorham, 1957; Heinselman, 1963, 1970; Moore and Bellamy, 1974) this prevents accurate determination of peat types and basin geometry from the present vegetation communities (Bastin and Davis, 1909; Dachnowski, 1926; Kennedy, 1963; NORTEC, 1980). Consequently, detailed field surveys are necessary to ascertain the stratigraphy and subsurface extent of peat deposits.

Freshwater wetlands in glaciated North America commonly occur in depressions resulting from Pleistocene glaciation (Dachnowski, 1926; Kennedy, 1963; Schafer and Hartshorn, 1965; Cameron, 1970a, b, 1975). Two models of wetland development are described for this region: 1) hydroseral succession (Dansereau and Segadas-Vianna, 1952; Daubenmire, 1968; Moore and Bellamy, 1974; Kurmis et al., 1978); and 2) paludification (Dachnowski, 1924; Heinselman, 1963, 1970; Moore and Bellamy, 1974; Kurmis et al., 1978). Depth and slopes of the original basin, hydrology, nutrient supply, climate, fires and human alteration are interrelated factors influencing wetland development (Gorham, 1957; Heinselman, 1963; Moore and Bellamy, 1974). Variations of these factors can cause wetland succession to deviate from the classical pathways of the two models. The two schools concur that during wetland development, peat results from accumulation of vegetative material in anaerobic environments associated with increasing congestion of surface drainage.

An oligotrophic (nutrient-poor, oxygen-rich) pond or lake occupying a closed glacial depression exemplifies the initial stage of hydroseral succession (Daubenmire, 1968). Submergent and floating plants become established along the shore and in areas where terrigenous deposition has reduced water depth to less than 2m. The pond or lake may change from oligotrophic to eutrophic (nutrient-rich, oxygen-depleted) when the remains of submergents and surface plants begin to accumulate as sedimentary peat. Further filling of the lake/pond permits the centripetal establishment of emergent vegetation represented by reed-sedge peat.

Anchored or floating marginal mats characterize the fourth stage of hydroseral succession. A thick, tangled mat of peat supporting moss and sedges originates along the margins of the wetland and encroaches towards the center. Moss peat accumulates in nutrient-poor water regimes while sedge peat is deposited under more nutrient-rich conditions (Daubenmire, 1968). Shrubs and trees invade whenever and wherever water depth will permit growth.

Paludification refers to "the process of bog [wetland] expansion caused by gradual rising of the water table as peat accumulation impedes drainage" (Heinselman, 1963). Peat stratigraphy resulting from paludification in the Lake Agassiz region of north-central Minnesota consists of basal forest peat overlain by moss peat, indicating forests invaded by bog. Basal sedimentary peat is absent or only locally significant (Heinselman, 1970). Wetlands resulting from paludification in Quebec, Ontario and Northern Europe (Dansereau and Segadas-Vianna, 1952; Gorham, 1957; Moore and Bellamy, 1974) originated as lake-filled basins that expanded over surrounding upland. In the North American and European examples, wetlands progress from a minerotrophic stage (nutrients and water derived from outlying, mineral soil) through more nutrient-poor conditions to an ombrotrophic stage (nutrients and water derived from rain).

The freshwater wetlands of Block Island originated as depressions in the late Wisconsinan, New Shoreham Formation. Elongate ponds and wetlands such as Fresh, Sands and Payne Ponds or Cooneymus, Franklin and Great Swamps (Fig. 3) occur in former meltwater channels blocked by deposition (Sirkin, 1976, 1981). Numerous, smaller wetlands occupy ice-block molds in till. Wetlands (#21, 36) on the west side of Corn Neck occur in glacial depressions that were probably separated from the ocean by barrier spit and foredune development.

Speculative outlines of succession can be drawn for each of the investigated wetlands on Block Island using peat stratigraphy, ash content, depth contour maps and the ground water hydrology map. Pollen analysis, radiocarbon dating, more cores and detailed hydrologic and nutrient investigations would be necessary to further support the following interpretations.

Basal sedimentary peat, signifying a lake or pond origin, is present in every investigated wetland except the Neptune Segment (Fig. 23). Basal sedimentary peat occurs in the deepest parts of basins and does not mantle entire basin bottoms. Emergent vegetation, which ultimately produces reed-sedge peat, can only grow in less than 1-2 m of water (Welch, 1952; Wetzel, 1975). Therefore, the limited extent of basal sedimentary peat and the considerable thickness of overlying peats (Fig. 23) indicates most of the investigated wetlands continued to develop by paludification.

Ambrose Swamp originated in an ice block-mold-in-till basin. The highest elevations of basal sedimentary peat occur in cores 7IA, 7IIA and 7IIB at 775, 500 and 310 cm respectively (App. 2A). Reed-sedge at the bottom of core 7IC indicates a continuous mantle of basal sedimentary peat does not cover the entire basin bottom. Sedimentary peat in core 7IIA and more especially in 7IIB probably accumulated in small isolated ponds similar to those on the present surface of Ambrose (Figs. 21, 22A).

Peat stratigraphy (Fig. 23) and ash content reflect the successional development of Ambrose Swamp. The deepest sedimentary peat marks the transformation from oligotrophic to eutrophic conditions and consequently has high ash content (Fig. 32). The abrupt decrease in ash content between sedimentary peat and overlying peat types approximates the beginning of paludification. An upward decreasing ash content in peats from raised bogs of Northumberland, England is linked to the declining nutrient levels responsible for transition from minerotrophic to ombrotrophic conditions (Chapman, 1964). Ambrose Swamp is not a raised bog, but decreasing ash content through the reed-sedge and moss peat (Fig. 32) does indicate a trend towards more nutrient-poor conditions.

Peat stratigraphy in Franklin Swamp (Fig. 23, App. 2 B,C,D) indicates "retrogressive succession" associated with a rising water table (Golet and Parkhurst, 1981). Two sequences of sedimentary and reed-sedge peat are present in the 8 m deep main basin. Hydroseral succession of a pond within the confines of the 500 cm contour interval (Fig. 25B) was responsible for deposition of the lower sedimentary peat and reed-sedge sequence. The depth of the small basin at the northeast end of Franklin suggests a possibility for tne presence of the lower sequence but core 4IVB terminates at too shallow of a depth to verify this hypothesis (Fig. 23).

A rise in water table approximating the 300 cm contour interval (Fig. 25B) formed a larger pond in which the upper sedimentary peat accumulated. The depth contours of Franklin do not favor a rise in water table associated with blockage of a drainage outlet; and a 1 m per 745 yr peat accumulation rate (Davis, 1946 in Cameron, 1970; Potzger and Courtemarche, 1954) would not permit deposition of the overlying peat thickness if retrogression resulted from peat harvesting during colonial times.

A wetter climate, such as mild, wet conditions during the hypsithermal (6500-7500 yr BP: Newman, 1977; Ogden, 1977), is an alternative explanation for the elevated water table. Prominent indication of climatic change is not obvious in peat stratigraphy from most of the other investigated wetlands. Pollen analysis of other island peat deposits (including Franklin Swamp) is necessary to verify the stratigraphic suggestion of a climatic change.

The uppermost reed-sedge interval results from paludification. Cattail or other marsh plants expanded across shallow ridges (Fig. 25B) into smaller, outlying basins to form a large contiguous marsh. The present surface of Franklin Swamp is representative of an extensive reed-sedge depositional environment.

Peat in Franklin Swamp has a higher ash content than peats deposited in Ambrose Swamp (Fig. 32). The complex successional history and hydrologic position of Franklin are considered to be responsible for these differences. Franklin Swamp lies in the lower perched water zone/main zone of saturation while Ambrose is a perched wetland (Fig. 4). Wetlands in contact with the regional water table often have higher nutrient levels than perched wetlands (Bay, 1967a, b). Springs and drainage from a smaller wetland to the north of Franklin (Fig. 25A) also serve as terrigenous (ash) sources. Sedimentary peat, confined to depths exceeding 3 m in East Great Swamp (App. 2E, Fig. 23), indicates the wetland originated as a small pond. Reed-sedge was deposited in peripheral marshes that expanded outward to the present day border of the wetland. Extremely high ash contents (Fig. 33) probably result from deposition of terrigenous material by a deranged drainage pattern resembling contemporary conditions (Fig. 27A).

Thickness and extent of sedimentary peat (Fig. 23, App. 2F,G) indicate West Great Swamp originated as two separate ponds lying below the 200 cm contour (Fig. 27B). Reed-sedge was deposited in peripheral marshes or fens and eventually expanded over the northwest striking ridge separating the two basins. At the north end of the wetland, the greatest distance from nutrient-rich runoff entering at the south end, the contemporaneous development of a bog mat began. Moss peat thins to the south (Fig. 23) and indicates the entire wetland was at one time covered by bog.

Deposition of moss peat continued until an outlet exceeding the 200 cm contour (Fig. 27B) developed at the northeast end of the wetland. This drainage into East Great Swamp would have resulted in a greater and more uniform distribution of nutrients, permitting re-establishment of marsh and deposition of the upper reed-sedge peat. Moss peat overlying reed-sedge in cores 6IA and 6D indicate localized areas of bog developed following re-establishment of the marsh. The lower no recovery zone in core 6E might result from a re-floating of the peat mat. Similar flotations have been described by Gleason et al. (1980) for peat islands in the Everglades.

Ash content is extremely high in the basal sedimentary peat, but immediately above this is low ash moss peat (Fig. 33B). The upper reed-sedge has a higher ash content and corresponds to more nutrient-rich conditions associated with opening of the outlet.

Basal reed-sedge indicates the Neptune Segment originated as shallow marsh that was flooded and covered by lake silts and sedimentary peat (App. 2H, Fig. 23). Lake level approximated the 300 cm contour (Fig. 27B). This retrogressive succession may have resulted from a climatically induced rise in water table as in Franklin Swamp. An influx of drainage from the other two basins of Great Swamp is another possible cause for a retrogressive flooding of the Neptune Segment. Open water succeeded to marsh and the upper reed-sedge interval was deposited. Core 2ID (Fig. 33C) is a composite of a 2 m section which prohibits observations of variations in ash content.

New Meadow Hill Swamp is comprised of two wetlands (Fig. 29A). Drumlins (Sirkin, 1976) divide the swamp into East (#204) and West (#205) parts and also separate the wetland complex from brackish waters of Trims and Harbor Ponds. Unless deposition occurred at a faster rate, the depth and thickness of basal sedimentary peat (App. 2I-L, Fig. 23) in the West basin indicates this part of New Meadow Hill Swamp is older than the East basin.

The sedimentary peat/reed-sedge contact in core 3IIC approximates the original pond surface. Marsh or fen around edges of the pond were responsible for reed-sedge deposition. The water table in the wetland rose with the accumulation of reed-sedge and emergent vegetation expanded over the elongate, southeastern appendage of the West basin (Fig. 29B).

A drastic change in the surface of West New Meadow Hill Swamp is documented by four sets of aerial photographs (1952, 1963, 1972, 1975). In 1952, a mosquito ditch crossed the length of the wetland through an extensive stand of cattail (DM-4) containing several small areas of open water. Eleven years later, areas of open water had tripled in size and represented approximately half of the wetland area. A cooling lagoon was constructed for the power plant in the late 1960's and by 1972, West New Meadow Hill was similar to present day (Figs. 28, 30).

Collective effects of mosquito ditching, Hurricane Carol (1954), and muskrat "eatouts" similar to those described by Weller and Spatcher (1965) are potential causes for the first 11 years of change. Since the late 1960's, construction of the cooling lagoon, muskrats, and the remaining ditches, may have been responsible for the continuing change in the surface of the wetland. Whatever the cause, the retrogressive succession occuring between 1952 and 1975 does help to account for the 4-6 m zone of no recovery in the center of the main basin (Fig. 23).

Stratigraphy of East New Meadow Hill Swamp is more complex than West New Meadow Hill Swamp (Fig. 23). Basal sedimentary peat was deposited in a pond lying below the 200 cm contour interval (Figs. 23,29B). Succession progressed to either marsh or fen and reed-sedge peat was deposited. Moss peat in cores 3IVB and 3IVC (App. 2L, Fig. 23) indicate bog developed over marsh in the center of the wetland. No estimation of east-west width of the bog can be made as moss peat does not appear in core 3IIIB or 3IVD (App. 4). Reed-sedge in cores 3IVD and 3IIIB indicate the marsh or fen surrounding the bog continued to expand until the East and West parts of New Meadow Hill Swamp were united.

In New Meadow Hill Swamp, as in the other investigated wetlands (Figs. 32-34), peat-fuel quality is related to peat type or ultimately the successional development of a wetland. The sedimentary peat initially deposited in a wetland has excessively high ash content and low BTU value (Table 3). Reed-sedge has variable fuel quality (Table 3) and is strongly dependent on the successional history of the wetland. Ambrose, West Great and East New Meadow Hill Swamps contain fuel-grade, reed-sedge peat. Stratigraphy and ash content of the three wetlands indicates succession progressed towards more nutrient-poor conditions. Reed-sedge in Franklin, East Great Swamp and the Neptune Segment has high ash content and resulting low BTU values due to either retrogressive wetland succession or water abundant in nutrients. Every analyzed interval of moss peat (App. 4, Figs. 32-35) is of fuel quality and results from the nutrient-poor to ombrotrophic conditions essential for development of bogs.

Fuel Analyses

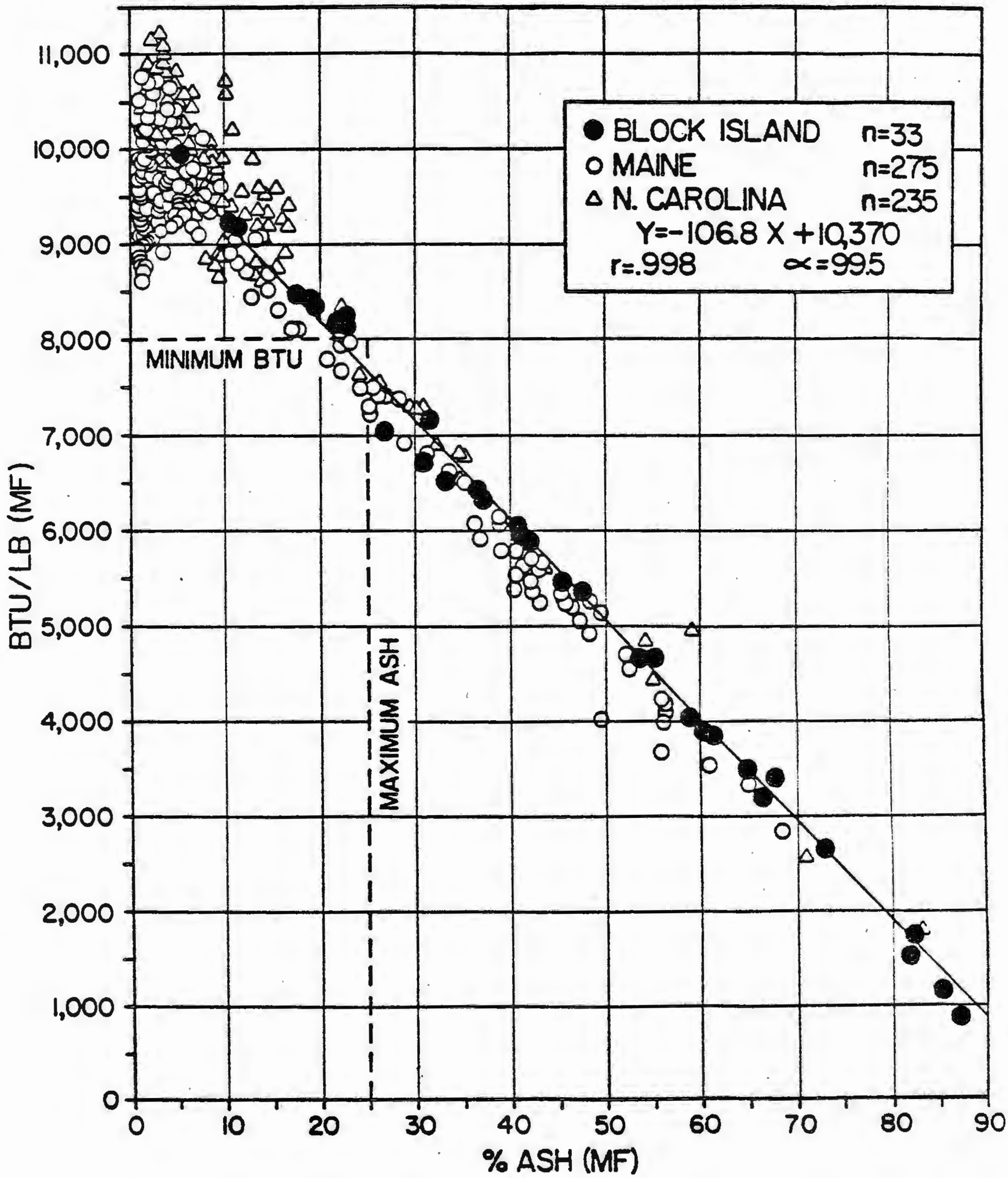
Conventional methods of coal analysis were used in the fuel analysis of peat cores from Block Island (App. 4). Proximate analysis is performed to determine the behavior of moisture, volatile matter, fixed carbon and ash when coals are heated. Ultimate analysis provides the elemental composition of coals. Heating value is determined by calorimetry but can also be empirically derived from moisture content, volatile matter or select components of ultimate analysis (Ergun, 1979).

In the assessment of fuel-grade peat resources, ash content and heating value are of primary concern. Fuel-grade peat (US DOE, 1980) has less than 25% ash and yields more than 8,000 BTU/lb (MF). Figure 35 indicates a significant inverse relationship between BTU and ash. A similar linear relationship was observed by Otte and Ingram (1980) and is further substantiated by data from other peat resource investigations (Fig. 36).

The import of a linear relationship between BTU and ash is readily applicable to fuel-peat resource investigations. Complete fuel analysis of one peat sample costs $83.70 (US DOE, 1980) and requires elaborate equipment. Ash content of peat is easily determined by incinerating the sample at

Fig. 36.—Relationship of BTU/lb to ash in 543 moisture-free peat samples from Maine (Davis et al., 1980) North Carolina (Otte and Ingram, 1980) and Block Island, Rhode Island. Regression line refers to the 33 samples from Block Island.

BTU vs ASH CONTENT



550C in a muffle furnace (Cameron, 1970a; ASTM, 1978). Heat value can be graphically derived from ash (MF) in Figure 35 or with the equation:

$$BTU/lb = -106.76(\%\ ash) + 10370.21.$$

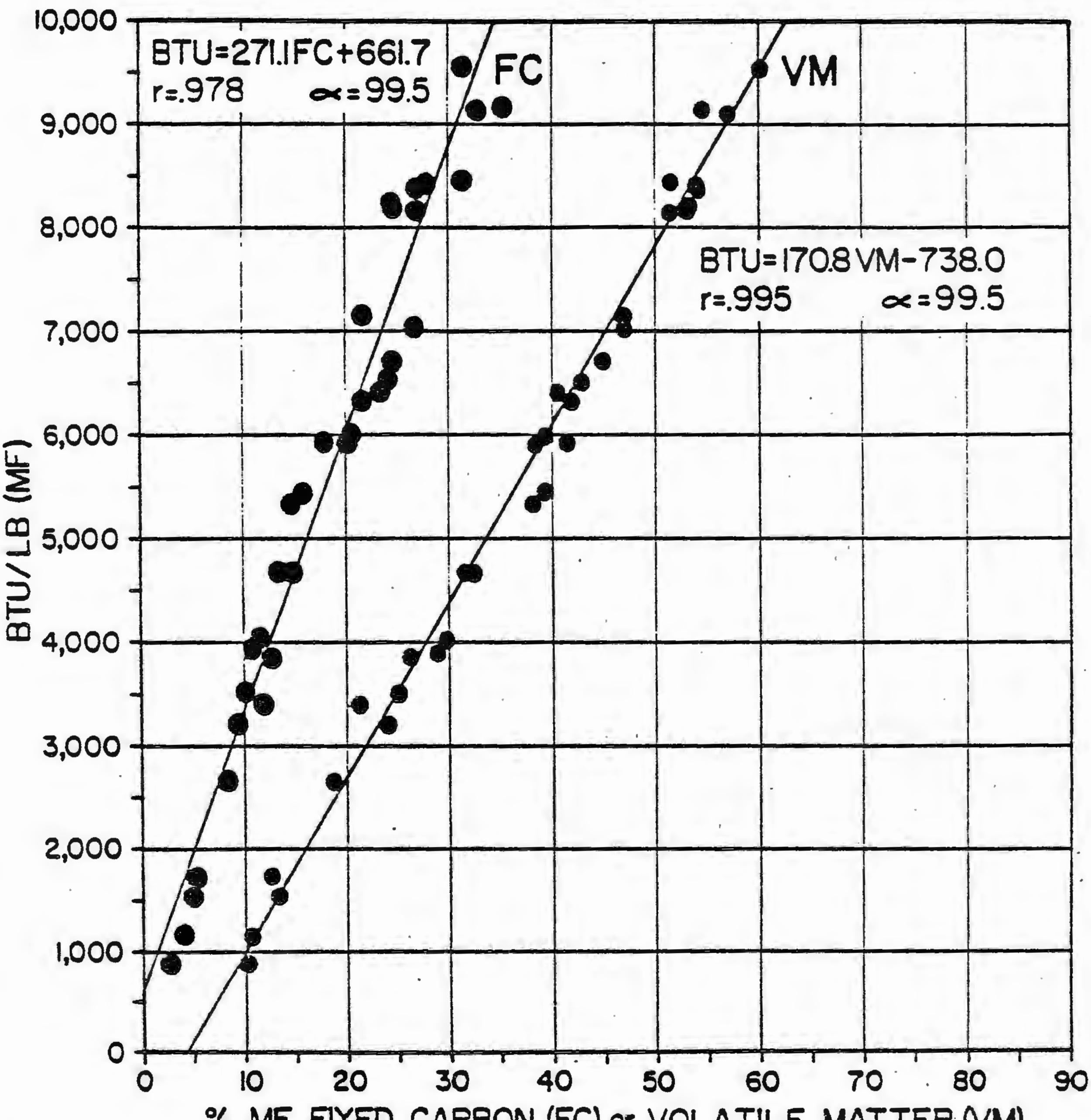
A complete fuel analysis is essential in determining properties of fuel-grade peat resources; however, the BTU - ash relationship provides an inexpensive and rapid index of heating value.

Volatile matter and fixed carbon provide the combustive energy of peat. During proximate analysis, both are determined from moisture-free peat. Volatile matter consists of combustible and incombustible gases. Fixed carbon is the weight of devolatized peat less ash (Ergun, 1979; Harker and Allen, 1972). Much of the combustive energy in peat is derived from fixed carbon (US DOE, 1979). This is apparent when the effects of fixed carbon and volatile matter on heating value of peats from Block Island are compared (Fig. 37).

Volatile matter, consisting of carbon, hydrogen and oxygen, and fixed carbon contribute to heating value (Ergun, 1979). Nitrogen and sulfur, the other elements determined during ultimate analysis, have little effect on heating value but are sources of pollution (Essenhigh, 1979; Ergun, 1979; Massey, 1979). Nitrogen and sulfur ranges in fuel-grade peat from Block Island are 0.04-2.33% and 0.58-0.97% respectively (App. 4). Nitrogen content is comparable to that of coal (1-2%) and sulfur is within

Fig. 37. — Relative effects of fixed carbon (FC) and volatile matter (VM) on BTU/lb of moisture-free peats from Block Island, Rhode Island.

BTU vs FIXED CARBON & VOLATILE MATTER



the range of low sulfur (<1%) coal (Eliot, 1978; Ergun, 1979).

Fuel-Grade Peat Resource

The combined resource of fuel-grade peat from Ambrose, West Great and New Meadow Hill Swamps is 27,360 tonnes (Table 5). This calculated resource is conservative as the 1-3 m zone of no recovery (Fig. 23) overlying fuel-grade peat is probably of fuel quality. J. Pecoraro, of the Massachusetts Office of Energy Resources, indicates a one megawatt power plant consumes 5,833 short tons (5,206 MT) of peat per year (Boothroyd et al., 1979). Thus, fuel-grade peat from the three wetlands could fuel a one megawatt power plant for 5.25 years. The 24,210 MT of peat considered to exist in the no recovery zones of Ambrose, West Great, East and West New Meadow Hill Swamps (Table 5) would supply an additional 4.65 years of power plant fuel.

Peat from Ambrose, West Great and East New Meadow Hill Swamps and any other wetlands meeting fuel-grade criteria could be harvested to supply power for the island community. Open space surrounding harvestable wetlands or abandoned gravel pits are likely sites to air-dry the peat. Conversion of the present one megawatt diesel-fired power plant or construction of a new gasification power plant is necessary to utilize the peat as an industrial fuel source.

An alternate method of peat utilization is for home heating. Rhode Island households annually use 2.8 cords of wood to supplement other heating facilities or 5.25 cords of wood as a primary fuel source (Stoddard, 1979). For comparison purposes, best quality fuel wood yields 7950 BTU/lb and weighs 2 tons per cord (Parsons, 1979). The average heating value of air-dried, fuel-grade peat from Block Island is 5612 BTU/lb. Thus peat is 70% as efficent as the best fuel wood. On this basis, the 27,360 tonnes (30,560 short tons) of fuel-grade peat in Ambrose, West Great and East New Meadow Hill Swamps could supply 100 homes with 38 years of supplemental fuel or 20 years of primary fuel. The supply of supplemental and primary fuel would be increased by 30 and 16 years respectively, if the 24,210 MT of fuel-grade peat expected to exist in zones of no recovery (Table 5) are included.

The environmental effects of harvesting peat from wetlands of Block Island requires an extensive study encompassing but not limited to: ground water hydrology and selection of harvesting equipment (King et al., 1980). However, some preliminary issues can be addressed.

Would harvesting affect the quality and specific yield of public wells utilizing aquifers in the discontinuously-superimposed upper perched water bodies and lower perched water zones of Block Island (Fig. 4)? The areal extent and effect of peat harvesting within the ground water system must be identified by determining the wetland's hydrologic connection with adjacent aquifers and selecting a suitable harvesting technique.

Mechanical and hydraulic harvesting are the major commercial methods of peat harvesting (U.S. DOE, 1979). Mechanical harvesting requires clearing and draining the wetland so that peat can be compressed into sods or milled into shreds by machinery. Drainage and the subsequent disposal of water are factors to be considered. Alternatively, hydraulic harvesting pumps the peat at natural water content as a slurry to a dewatering facility (solar, mechanical or chemical).

Draining a wetland for harvest, or dewatering facilities not returning the water to the wetland would affect the hydrologic character of the wetland and possibly adjacent aquifers. Consequently, a harvesting technique with dewatering facilities returning water back to the wetland would be least disruptive hydrologically.

CONCLUSIONS

1) The 216 freshwater wetlands on Block Island cover 121.23 ha and range in size from 0.05 to 7.89 ha. Forty five percent of the total wetland area consists of wetlands smaller than a hectare.

2) Seven classes and thirteen subclasses of freshwater wetland are present on Block Island. Wooded swamp is absent. Surface vegetation can not be used to predict quality or thickness of peat.

3) Peat stratigraphy from 7 investigated wetlands indicates hydroseral succession and paludification were responsible for wetland development.

4) Peat resources of Ambrose, Franklin, East and West Great, the Neptune Segment and East and West New Meadow Hill Swamps were determined. The 7 wetlands cover 21.02 ha and range in size from 0.9 to 7.89 ha. Maximum depth is 3 to 12 m. Combined peat resource of the 7 investigated wetlands is 92,250 MT (at 35% moisture). Resource of the individual wetlands ranges from 1,920 to 32,500 MT.

5) Fuel analysis of 33 peat samples from the 7 investigated wetlands have moisture-free BTU/lb and ash ranges of 887-9560 and 8.90-87.35% respectively. A highly significant inverse relationship exists between moisture free BTU/lb and ash and is defined by the equation:

$$\text{BTU/lb} = -106.76\ (\%\ \text{ash}) + 10370.21.$$

6) Ash content of the three peat types results from the

successional history of the wetland. Sedimentary peat most commonly occurs at the bottom of wetlands and has excessively high (>36%) ash. Reed-sedge is of variable fuel quality due to range of ash content (17-34%). Moss peat has low ash content (<19%) and is always fuel grade (<25% ash, >8000 BTU/lb MF).

7) Fuel grade peat occurs in Ambrose, West Great and East New Meadow Hill Swamps. The combined resource of fuel grade peat in the three wetlands is 27,360 MT and could furnish fuel to a one megawatt electricity-generating power plant for 5.25 years or 100 homes for 20-38 years.

8) Fuel grade peat in the zones of no recovery in Ambrose, West Great, and East and West New Meadow Hill Swamps could provide an additional 24,210 MT and would increase the supply of power plant fuel by 4.65 yrs or home heating fuel by 16-30 yrs.

REFERENCES

Abramova, T.G., 1965, The indicator significance of the vegetation cover of the bogs of Leningrad Province, in Chikishev, A.G., ed., Plant indicators of soils, rocks and subsurface waters: New York, Consultants Bureau, p. 66-80.

American Society of Testing and Materials, 1978, Standard methods for moisture, ash and organic matter of peat materials: 1978 Annual Book of ASTM Standard pt. 19: Philadelphia, ASTM, p. 399-400.

Avery, T.E., 1977, Interpretation of aerial photographs: Minneapolis, MN, Burgess Publ. Co., 392 p.

Bastin, E.S., and Davis, C.A., 1909, Peat deposits of Maine: U.S. Geol. Survey Bull. 376, 127 p.

Bay, R.R. 1967a, Ground water and vegetation in two peat bogs in northern Minnesota: Ecology, v. 48, p. 308-310.

-----, 1967b, Factors influencing soil-moisture relationships in undrained forested bogs, in Soper, W.E., and Lull, H.W., eds., Forest Hydrology: New York, Pergamon Press, p. 335-343.

Boch, M.S., 1965, The present position of the problem of the utilization of the indicator role of the vegetation cover of bogs in relation to the structure and properties of peat deposits, in Chikishev, A.G., ed., Plant indicators of soils, rocks and subsurface water: N.Y., Consultants Bureau, p. 61-65.

Boothroyd, J.C., Peters, C.R., and Pickart A.J., 1979, Peat resources of Block Island: Technical report for Rhode Island Governor's Energy Office and U.S. Dept. of Energy, Grant No. DOEBO-365-8, 75 p.

Cameron, C.C., 1970a, Peat deposits of northeastern Pennsylvania: U.S. Geol. Survey Bull. 1317-A, 90 p.

-----, 1970b, Peat deposits of southeastern New York: U.S. Geol. Survey Bull. 1317-B, 32 p.

-----, 1975, Some peat deposits in Washington and southeastern Aroostook Counties, Maine: U.S. Geol. Survey Bull. 1317-C, 40 p.

Chapman, S.B., 1964, The ecology of Coom Rigg Moss, Northumberland, II. The chemistry of peat profiles and the development of the bog system: Jour. Ecol., v. 52, p.

315-321.

Cowardin, L.M., Carter, V., Golet, F.C., and LaRoe, E.T., 1979, Classification of wetlands and deep water habitats of the United States: U.S. Fish and Wildlife Service, Office of Biological Services, 103 p.

Dachnowski, A.P., 1924, The stratigraphic study of peat deposits: Soil Science, v. 17, p. 107-133.

-----, 1926, Profiles of peat deposits in New England: Ecology, v. 7, p. 120-135.

Dansereau, P., and Segadas-Vianna, F., 1952, Ecological studies of the peat bogs in eastern North America: I. structure and evolution of vegetation: Canad. Jour. Bot., v. 30, p. 490-520.

Daubenmire, R., 1968, Plant communities: a textbook in plant synecology: New York, Harper and Row, 300 p.

Davies, E.G., 1945, Figyn Blaen Brefi: a Welsh upland bog: Jour. Ecology, v. 32, p. 147-166.

Davis, J., Anderson, W., and Cameron, C.C., 1980, Peat resource evaluation, state of Maine: Final report for U.S. Dept. of Energy, Grant No. DEFG01-79ET 14690, 17 p.

Davis, J.H., Jr., 1946, The peat deposits of Florida, their occurence, development and uses: Florida Geol. Survey Bull., v. 30, 247 p.

Edgerton, C.D., 1969, Peat bog investigations in northeastern Pennsylvania: Penna. Geol. Survey Bull. IC 65, 53 p.

Eliot, R.C., 1978, Coal combustion, in Wen, C.Y., and Lee, E.S., eds., Coal Conversion Technology: Reading, MA, Addison-Wesley, p. 171-312.

Ergun, S., 1979, Coal classification and characterization, in Wen, C.Y., and Lee, E.S., eds., Coal Conversion Technology: Reading, MA, Addison-Wesley Publishing Co., p. 1-56.

Essenhigh, R.H., 1979, Coal combustion, in Wen, C.Y., and Lee, E.S., eds., Coal Conversion Technology: Reading, MA, Addison-Wesley, p. 171-312.

Gleason, P.J., Piepgras, D., Stone, P.A., and Stipp, J., 1980, Radiometric evidence for involvement of floating islands in the formation of Florida Everglades tree islands: Geology, v. 8, p. 195-199.

Golet, F.C., and Larson, J.S., 1974, Classification of fresh water wetlands in the glaciated northeast: U.S. Fish and Wildl. Resour. Pub. 116, 56 p.

-----, 1979, Rating the wildlife value of northeastern fresh water wetlands: in Greeson, P.E., Clark, J.R., and Clark, J.E., Wetland functions and values: The state of our understanding: Minneapolis, MN, American Water Resour. Assn., p. 63-73.

Golet, F.C., and Parkhurst, J.A., 1981, Freshwater wetland dynamics in South Kingstown, Rhode Island, 1939-1972: Environ. Mgt., v. 5, p. 245-251.

Goodwin, R.H., and Niering, W.A., 1974, Inland wetlands: Their ecological role and environmental status: Bull. Ecol. Soc. America, v. 55, no. 2, p. 2-6.

Gorham, E., 1957, The development of peatlands: Quart. Rev. Biol., v. 32, p. 145-166.

Guthrie, R.C., and Stolgitis, J.A., 1977, Fisheries investigations and management in Rhode Island lakes and ponds, R.I. Div. Fish and Wildlife, Fisheries Report no. 3, 256 p.

Hansen, A.J., Jr., and Schiner, G.R., 1964, Ground-water resources of Block Island, Rhode Island: R.I. Geol. Bull., no. 14, 35 p.

Harker, J.H., and Allen, D.A., 1972, Fuel science: Edinburgh, Scotland, Oliver and Boyd, 195 p.

Heinselman, M.L., 1963, Forest sites, bog processes, and peatland types in the Glacial Lake Agassiz Region, Minnesota: Ecol. Monogr., v. 33, p. 327-374.

-----, 1970, Landscape evolution, peatland types and the environment in the Lake Agassiz Peatlands Natural Area, Minnesota: Ecol. Monogr., v. 40, p. 235-261.

Jackson, C.T., 1840, Report on the geological and agricultural survey of the state of Rhode Island: Providence, RI, B. Cranston and Co. 312 p.

Jeglum, J.K., Boissoneau, A.N., and Haavisto, V.G., 1974, Toward a wetland classification for Ontario: Can. For. Serv. Inf. Rep. O-X-215, 54 p.

Kaye, C.A., 1960, Surficial geology of the Kingston quadrangle, Rhode Island: U.S. Geol. Survey Bull. 1071-I, 396 p.

Kennedy, R.A., 1963, The relationship of maximum peat depth to some environmental factors in bogs and swamps in Maine: Maine Agric. Exp. Stat., Univ. Maine Bull. 620, 55 p.

King, R., Richardson, S., Walters, A., Boesch, L., Thomson, W., and Irons, J., 1980, Preliminary evaluation of environmental issues on the use of peat as an energy source: Technical report for U.S. Dept. of Energy, Contract No. ET-78-C-01-3117, 200 p.

Kupa, J.J., and Whitman, W.R., 1972, Land-cover types of Rhode Island: an ecological inventory: Univ. Rhode Island Agr. Exp. Stat. Bull. 409, 30 p.

Kurmis, V., Hansen, H.L., Olson, J.J., and Alo, A.R., 1978, Vegetation types, species and areas of concern and forest resources utilization of northern Minnesota's peatlands, University of Minnesota, 87 p.

Larson, J.S., ed., 1976, Models for assessment of fresh-water wetlands: Univ. Mass., Amherst, Water Resour. Res. Center, Publ. 32, 91 p.

Livermore, S.T., 1961, History of Block Island, Rhode Island: Forge Village, MA, Murray Printing Co., 371 p.

MacConnell, W.P., 1974, Remote sensing, land use and vegetative cover in Rhode Island: Univ. Rhode Island Cooperative Ext. Ser. Bull. no. 200, 93 p.

Massey, L.G., 1979, Coal gassification for high and low Btu fuels, in Wen, C.Y., and Lee. E.S., eds. Coal Conversion Technology: Reading, MA, Addison-Wesley Pub. Co., p. 313-427.

Moore, P.D., and Bellamy, D.J., 1974, Peatlands: New York, Springer Verlag, 221 p.

Newman, W.S., 1977, Late Quaternary paleoenvironmental reconstruction: Some contradictions from northwestern Long Island, New York, in Newman, W.S., and Salwen, B., eds., Amerinds and their paleoenvironments in northeastern North America: Ann. N.Y. Acad. Sci., v. 288, p. 545-570.

Northern Technical Services, 1980, Supplemental report to peat resource estimation in Alaska: Final Report v. I, Anchorage, AK, 45 p.

Odum, E.P., 1979, The value of wetlands: a hierarchial approach: in Greeson, P.E., Clark, J.R., and Clark, J.E., Wetland functions and values: The state of our understanding: Minneapolis, MN, American Water Resour.

Assn., p. 16-25.

Ogden, J.G. III, 1977, The Late Quaternary paleoenvironmental record of northeastern North America, in Newman, W.S., and Salwen, B., eds., Amerinds and their paleoenvironments in northeastern North America: Ann. N.Y. Acad. Sci., v. 288, p. 16-34.

Otte, L.J., and Ingram, R.L., 1980, Peat resources of North Carolina: Annual report for the U.S. Dept. of Energy, Contract No. DE-AC01-79ET-14693, 60 p.

Parkhurst, J.A., 1977, Freshwater wetland dynamics and related impacts on wildlife in South Kingstown, Rhode Island, 1939-1972: unpub. M.S. thesis, Univ. Rhode Island, Kingston, RI, 104 p.

Potzger, J.E., and Courtemanche, A., 1954, A radiocarbon date from James Bay in Quebec: Science, v. 119, p. 908-909.

Parsons, R.A., ed., 1979, Burning wood: Cooperative Ext., Northeast Regional Agric. Eng. Ser., NE-191, 30 p.

Rhode Island, 1971, An act relating to "Fresh Water Wetlands": General Laws, chap. 2-1, sect. 18-24.

Rhode Island Coastal Resources Management Council, 1977, Coastal Mapping Project.

Rigg, G.B., 1940, The development of sphagnum bogs in North America: Bot. Rev. v. 6, p. 666-693.

Schafer, J.P., and Hartshorn, J.H., 1965, The Quarternary of New England, in Wright H.E. Jr., and Frey, D.G., eds., The Quarternary of the United States: Princeton, NJ, Princeton Univ. Press, p. 113-128.

Sirkin, L.A., 1976, Block Island, Rhode Island: Evidence of fluctuation of the late Pleistocene ice margin: Geol. Soc. America Bull., v. 87, p. 574-580.

-----, 1981, Pleistocene geology of Block Island, in Boothroyd, J.C., and Hermes, O.D., eds., Guidebook to geologic field studies in Rhode Island and adjacent areas: New England Intercoll. Geol. Conf., 73 rd Ann. mtg., Univ. Rhode Island, Kingston, RI, p. 35-46.

Sirkin, L.A., and Stuckenrath, R., 1980, The Portwashingtonian warm interval in the northern Atlantic coastal plain: Geol. Soc. America Bull., part 1, v. 91, p. 332-336.

Soil Survey Staff, 1975, Soil Taxonomy: a basic system of soil classification for making and interpreting soil surveys: U.S. Soil Conservation Service, Agric. Handb. 436, 754 p.

Stoddard, W.R., 1979, Estimation of a demand function for household firewood usage in Rhode Island: unpub. M.S. thesis, Univ. Rhode Island, Kingston, RI, 73 p.

U.S. Bureau of the Census, 1980, Census of population and housing: U.S. Dept. of Commerce, v. 41, 9 p.

U.S. Bureau of Mines, 1969, Peat: in U.S. Bureau of Mines Mineral Yearbook, v. 1-2, p. 783-789.

U.S. Department of Energy, 1979, Peat prospectus: Technical information document sponsered by the U.S. D.O.E., Division of Fossil Fuel Processing, 79 p.

-----, 1980, Proceedings of the first technical contractor's conference on peat, Contract No. DEAC01-78ET10159, 332 p.

Verry, E.S., and Boelter, D.H., 1979, Peatland hydrology: in Greeson, P.E., Clark, J.R., and Clark, J.E., eds., Wetland functions and values: The state of our understanding: Minneapolis, MN, American Water Resour. Assn., p. 389-402.

Welch, P.S., 1952, Limnology, 2nd ed.: New York, McGraw-Hill, 538 p.

Weller, M.W., and Spatcher, C.S., 1965, Role of habitat in the distribution and abundance of marsh birds: Agric. and Home Econ. Exp. Sta., Iowa State Univ. of Sci. and Tech, Ames, Iowa, Spec. Report No. 43, 31 p.

Wetzel, R.G., 1975, Limnology: Philadelphia, W.B., Sanders Co., 741 p.

Woodworth, J.B., 1934, Geology of Block Island, in Woodworth, J.B., and Wigglesworth, E., Geography and geology of the region including Cape Cod, the Elizabeth Islands, Nantucket, Martha's Vineyard, No Man's Land and Block Island: Harvard Coll. Mus. Comp. Zoology Mem., v. 52, p. 219-233.

Yasnolpol'skaya, G.G., 1965, Experience in the use of geobotanical methods in the exploration of peat bogs in Siberia, in Chikishev, A.G., ed., Plant indicators of soils, rocks and subsurface waters: New York, Consultants Bureau, p. 86-90.

Young, H.E., and Stoeckler, E.G., 1961, A study of the relationship between vegetation and the depth of peat in swamp hardwood forests, Maine State Highway Commission, Soils Lab, Orno, Maine.

APPENDIX 1

Area of Individual Wetlands by Subclasses

1 Hectare (ha) = 2.47 Acres

SUBCLASSES

OW-1	Vegetated Open Water
OW-2	Nonvegetated Open Water
DM-3	Sub-shrub Deep Marsh
DM-4	Robust Deep Marsh
DM-5	Narrow-leaved Deep Marsh
SM-1	Robust Shallow Marsh
SM-2	Narrow-leaved Shallow Marsh
M-1	Ungrazed Meadow
SS-2	Bushy Shrub Swamp
SS-4	Aquatic Shrub Swamp
F-1	Emergent Fen
BG-1	Emergent Bog
BG-2	Shrub Bog

Wetland Number	Name	Wetland Area (ha)	OW-1	OW-2	EM-3	EM-4	EM-5	SM-1	SM-2	M-1	SS-2	SS-4	F-1	BG-1	BG-2
1		0.06		0.06											
2		0.09		0.09											
3		0.47				0.47									
4		0.50				0.50									
5		0.26	0.26												
6		0.35				0.35									
7		0.36				0.36									
8		0.28			0.28										
9		0.19		0.19											
10		0.09			0.09										
11		0.16		0.08							0.08				
12		0.05	0.05												
13		0.20	0.07			0.13									
14		0.06			0.06										
15	Little Sachem Pond	0.93		0.32	0.61										
16		0.61		0.61											
17		0.10		0.10											
18		0.38		0.38											
19	Long Lot Pond	0.40		0.12	0.28										
20		0.12			0.12										

Wetland Number	Wetland Name	Wetland Area (ha)	OW-1	OW-2	DM-3	DM-4	DM-5	SM-1	SM-2	M-1	SS-2	SS-4	F-1	BG-1	BG-2
21	Wash Pond	4.53		1.82		2.71									
22		0.33									0.33				
23	Garden Pond	0.43		0.10	0.33										
24		0.30		0.30											
25		0.19									0.19				
26		0.05						0.05							
27		0.13						0.13							
28	Clayhead Swamp	3.08		1.94	1.14										
29		0.08		0.08											
30		0.32		0.19		0.13									
31		0.70		0.19		0.13					0.38				
32		0.17	0.05								0.12				
33		0.23									0.23				
34		0.97						0.97							
35		0.29		0.29											
36		2.39				1.62	0.24				0.53				
37		0.34				0.34									
38		0.93			0.93										
39		0.40		0.40											
40		0.32		0.17									0.15		

Wetland Number	Wetland Name	Wetland Area (ha)	OW-1	OW-2	DM-3	DM-4	DM-5	SM-1	SM-2	M-1	SS-2	SS-4	F-1	BG-1	BG-2
41		0.69		0.19									0.50		
42	Georgian Swamp	2.02		0.69		1.33									
43		0.23								0.23					
44		0.12		0.12											
45		0.48						0.48							
46		0.09		0.09											
47		0.56				0.56									
48		0.11		0.11											
49		0.76						0.76							
50		0.11		0.11											
51	Betty Puckey Pond	0.35		0.35											
52		0.10			0.10										
53		0.12			0.12										
54		0.89		0.20	0.69										
55		1.01						1.01							
56		0.85						0.53			0.32				
57		0.17						0.17							
58		0.26						0.26							
59		0.15			0.15										
60		0.30		0.13		0.17									

Wetland Number Name	Wetland Area (ha)	OW-1	OW-2	DM-3	DM-4	DM-5	SM-1	SM-2	M-1	SS-2	SS-4	F-1	BG-1	BG-2
61	0.33		0.33											
62	0.25									0.25				
63	0.44			0.11	0.33									
64 Rodman Pond	0.93		0.93											
65	0.18		0.18											
66	0.27		0.27											
67	0.14		0.14											
68	0.69	0.29		0.40										
69 Siah's Swamp	3.44	1.66			1.25					0.53				
70	0.69		0.30			0.39								
71	0.05					0.05								
72	0.05		0.05											
73	0.05			0.05										
74	1.42		0.69	0.73										
75	0.61		0.21	0.40										
76	0.06		0.06											
77	0.11						0.11							
78	0.37		0.17		0.20									
79	0.06	0.06												
80	0.08		0.08											

Wetland Number	Name	Wetland Area (ha)	OW-1	OW-2	DM-3	DM-4	DM-5	SM-1	SM-2	M-1	SS-2	SS-4	F-1	BG-1	BG-2
81		0.28		0.28											
82		0.40						0.40							
83		0.07			0.07										
84	Franklin Swamp	7.89	0.30			6.17					1.42				
85		0.05	0.05												
86		0.16						0.16							
87		0.10	0.10												
88	Cooneymus Swamp	1.76	0.26			1.50									
89		0.30						0.30							
90		1.46	0.53											0.77	0.16
91		0.36						0.36							
92		0.77		0.77											
93		0.14		0.14											
94	Worden Pond	0.89		0.89											
95		0.09	0.09												
96		2.19									0.49			0.49	1.21
97		0.77		0.77											
98		0.34		0.34											
99		0.12		0.12											
100		0.12									0.12				

Wetland Number	Name	Wetland Area (ha)	OW-1	OW-2	DM-3	DM-4	DM-5	SM-1	SM-2	M-1	SS-2	SS-4	F-1	BG-1	BG-2
101		0.36		0.36											
102		0.26			0.26										
103		0.40		0.40											
104		0.11		0.11											
105		0.09		0.09											
106		0.06		0.06											
107		0.23				0.23									
108		0.13									0.13				
109		0.39		0.39											
110		0.10		0.10											
111	Deep Pond	0.40		0.40											
112		0.10		0.10											
113		0.70		0.21	0.49										
114		0.07		0.07											
115		0.58		0.19	0.39										
116		0.08		0.08											
117		0.61						0.61							
118		0.24		0.05	0.19										
119		0.11		0.11											
120		0.49		0.49											

Wetland Number	Name	Wetland Area (ha)	OW-1	OW-2	EM-3	EM-4	EM-5	SM-1	SM-2	M-1	SS-2	SS-4	F-1	BG-1	BG-2
121	Peckham Pond	4.74		3.24	0.20										1.30
122		0.18			0.18										
123		0.29													0.29
124		0.20		0.20											
125		0.05		0.05											
126	Fresh Swamp	3.40	1.09												2.31
127		1.30		0.61							0.69				
128		0.28				0.28									
129		0.08									0.08				
130		0.19		0.12							0.07				
131		1.09		1.09											
132		0.53											0.53		
133		0.08	0.08												
134		0.06									0.06				
135		0.12	0.12												
136		0.85		0.14	0.53						0.18				
137		0.09									0.09				
138		0.10			0.10										
139		0.61		0.61											
140		0.10	0.10												

Wetland Number Name	Wetland Area (ha)	OW-1	OW-2	DM-3	DM-4	DM-5	SM-1	SM-2	M-1	SS-2	SS-4	F-1	BG-1	BG-2
141	0.12		0.12											
142	0.11									0.11				
143	0.15									0.15				
144	0.22		0.06							0.16				
145	0.12									0.12				
146 John E's Pond	2.00		2.00											
147	0.93		0.12								0.81			
148	0.07					0.05								
149	0.41							0.41						
150 Payne Pond	0.77		0.77											
151	0.25		0.25											
152	1.50		1.50											
153	0.49		0.15				0.34							
154	0.19		0.19											
155	0.12						0.12							
156	0.06		0.06											
157	0.53	0.53												
158	0.12			0.12										
159	0.06		0.06											
160	0.06		0.06											

Wetland Number	Wetland Name	Wetland Area (ha)	OW-1	OW-2	EM-3	EM-4	EM-5	SM-1	SM-2	M-1	SS-2	SS-4	F-1	BG-1	BG-2
161		0.06		0.06											
162		0.12								0.12					
163		0.09						0.09							
164		0.19				0.19									
165		0.09		0.09											
166		0.36				0.16					0.20				
167		0.28								0.28					
168		0.38						0.26			0.12				
169		0.08		0.08											
170	Ambrose Swamp	2.59	0.05			0.13		1.46			0.95				
171		0.19		0.19											
172		0.14	0.09		0.05										
173		0.57		0.20	0.37										
174		0.07						0.07							
175		0.08						0.08							
176		0.17						0.17							
177		0.18						0.18							
178		0.93		0.93											
179		0.13						0.13							
180		0.24						0.24							

Wetland Number	Name	Wetland Area (ha)	OW-1	OW-2	EM-3	EM-4	EM-5	SM-1	SM-2	M-1	SS-2	SS-4	F-1	BG-1	BG-2
181		0.38						0.38							
182	Continental Pond	1.21		1.21											
183		0.15						0.15							
184	East Great Swamp	2.10				0.16	1.66				0.28				
185	West Great Swamp	1.78	0.24								1.01				0.53
186		0.06		0.06											
187		0.70		0.13							0.57				
188		0.10		0.10											
189	Neptune Segment	0.90			0.34						0.12				0.44
190		0.14		0.14											
191	Mill Tail Swamp	5.91		5.02		0.89									
192		0.43						0.30	0.13						
193		0.17						0.17							
194		0.09						0.09							
195		0.19						0.19							
196		0.09						0.09							
197		0.49						0.49							
198		0.16		0.16											
199		0.40						0.40							
200		0.54									0.54				

Wetland Number	Name	Wetland Area (ha)	OW-1	OW-2	EM-3	EM-4	EM-5	SM-1	SM-2	M-1	SS-2	SS-4	F-1	BG-1	BG-2
201		1.93			1.13			0.65			0.15				
202		0.21						0.21							
203		0.16									0.16				
204	E New Meadow Hill	2.12	0.52		0.53	0.95									0.12
205	W New Meadow Hill	3.64		2.83		0.81									
206		0.21						0.21							
207		0.22		0.22											
208		0.57			0.57										
209		0.57				0.57									
210		0.07		0.07											
211		0.07		0.07											
212		0.21			0.21										
213		0.05						0.05							
214		0.17		0.17											
215		0.12		0.12											
216		0.16		0.16											

	Wetland Area (ha)	OW-1	OW-2	EM-3	EM-4	EM-5	SM-1	SM-2	M-1	SS-2	SS-4	F-1	BG-1	BG-2
TOTALS	121.23	6.59	42.76	12.32	22.62	2.41	12.82	0.54	0.63	10.93	0.81	1.18	1.26	6.36

APPENDIX 2

Core Logs

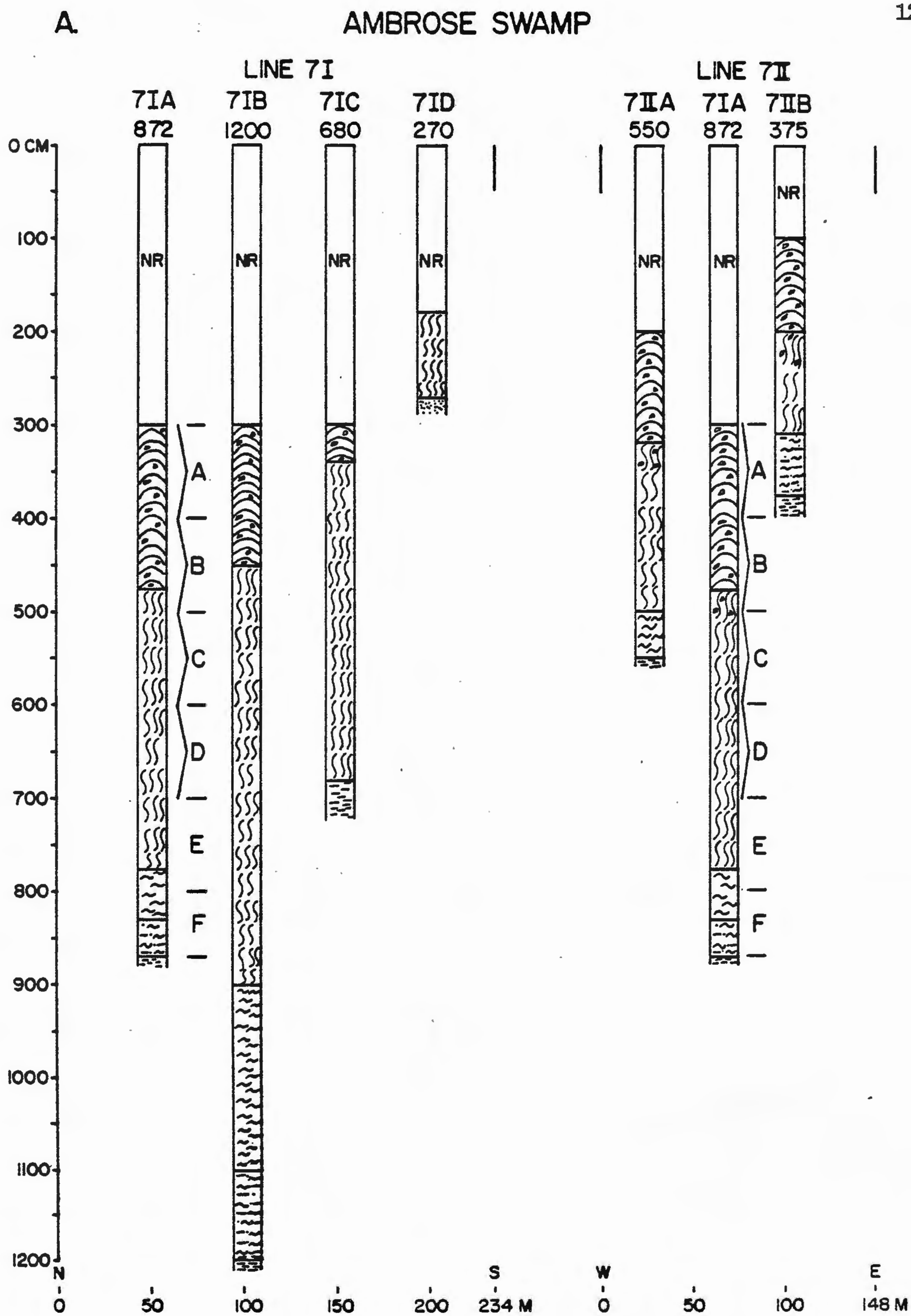
(A–L)

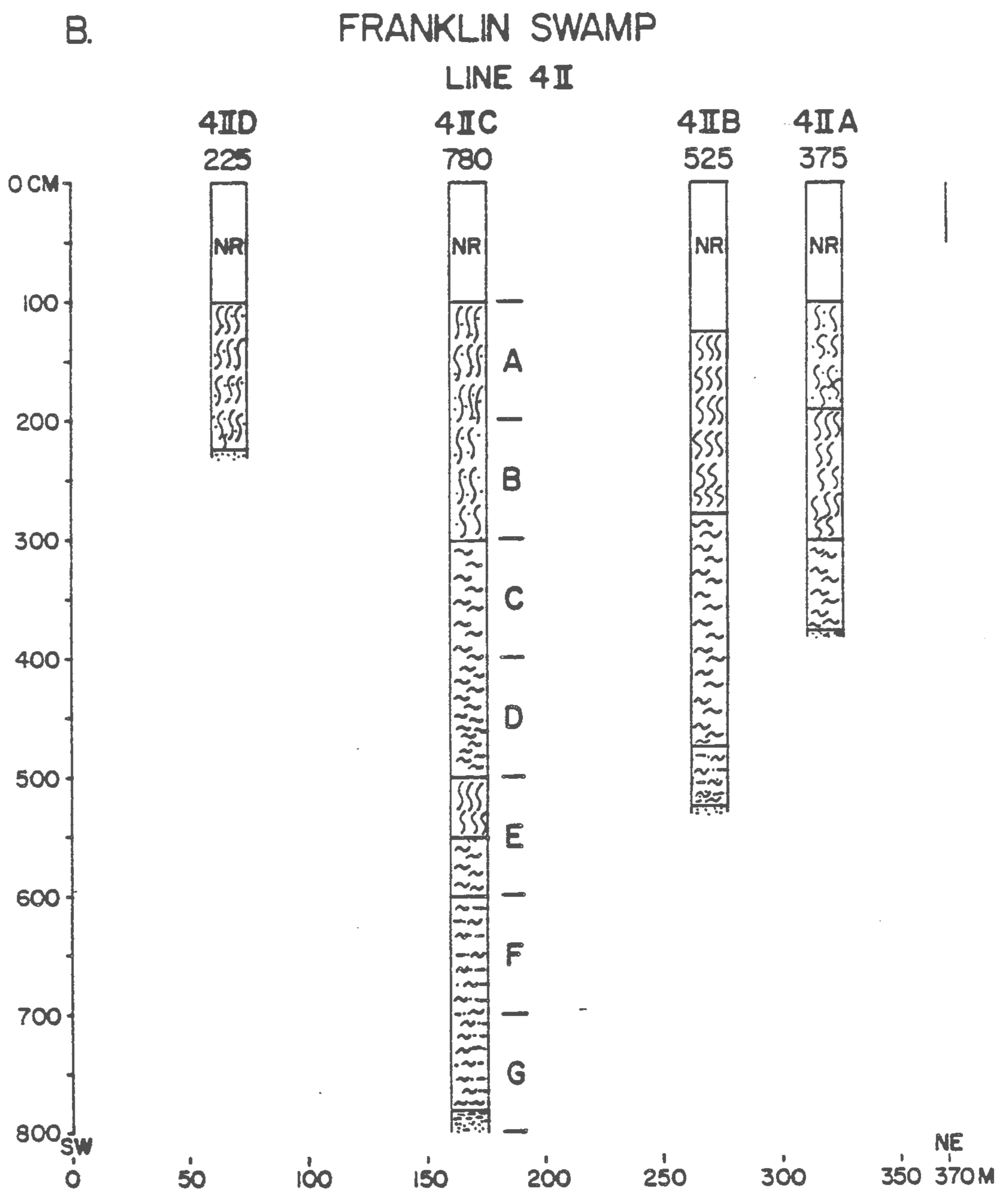
A	Ambrose Swamp
B-D	Franklin Swamp
E	East Great Swamp
F,G	West Great Swamp
H	Neptune Segment
I,J	West New Meadow Hill Swamp
K,L	East New Meadow Hill Swamp

Explanation to Peat Stratigraphy

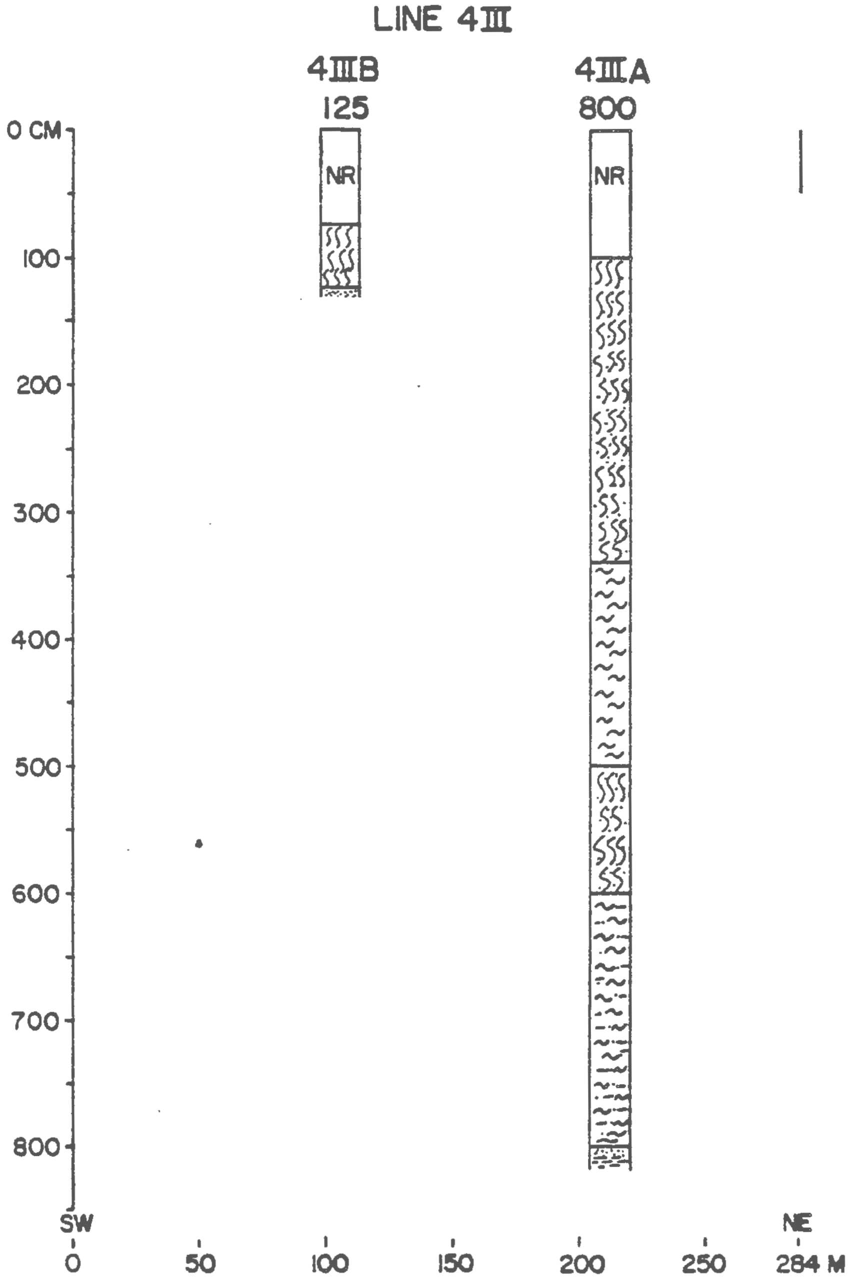
NR	No Recovery
	Moss Peat
	Reed-sedge
	Sedimentary
	Clay
	Sand

Letters along side of cores refer to analyzes core intervals in Appendix 4. ⟩ indicates core interval containing fuel-grade peat.

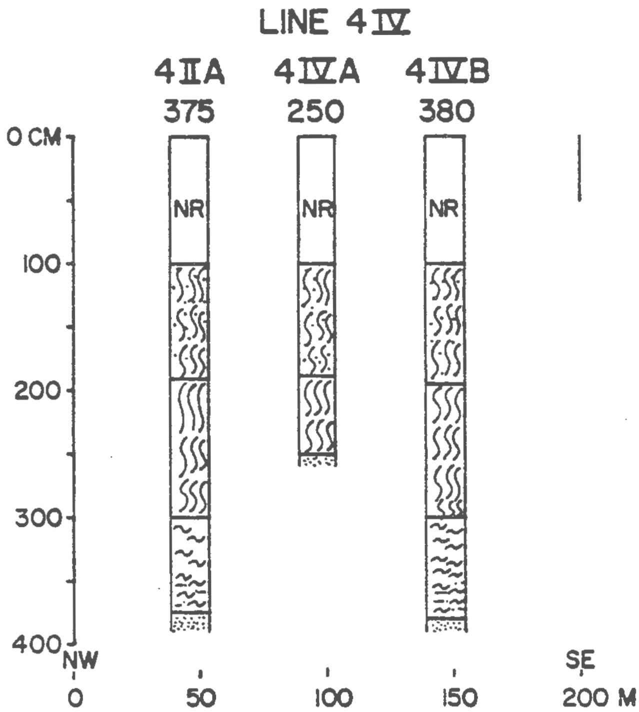

A.
AMBROSE SWAMP
LINE 7I
7IA
872
7IB
1200
7IC
680
7ID
270
LINE 7II
7IIA
550
7IA
872
7IIB
375
0 CM
100
200
300
400
500
600
700
800
900
1000
1100
1200
NR
A
B
C
D
E
F
N
S
W
E
0
50
100
150
200
234 M
0
50
100
148 M

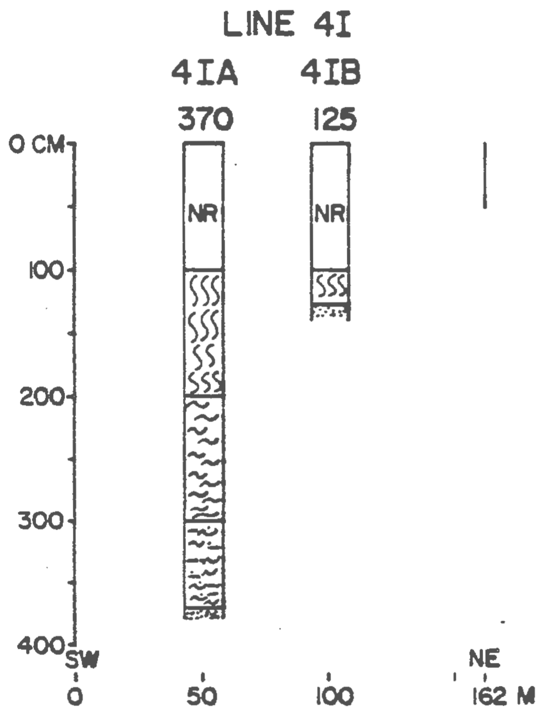

B.
FRANKLIN SWAMP
LINE 4II
4IID
225
4IIC
780
4IIB
525
4IIA
375
0 CM
100
200
300
400
500
600
700
800
NR
NR
NR
NR
A
B
C
D
E
F
G
SW
NE
0
50
100
150
200
250
300
350
370M

C. FRANKLIN SWAMP

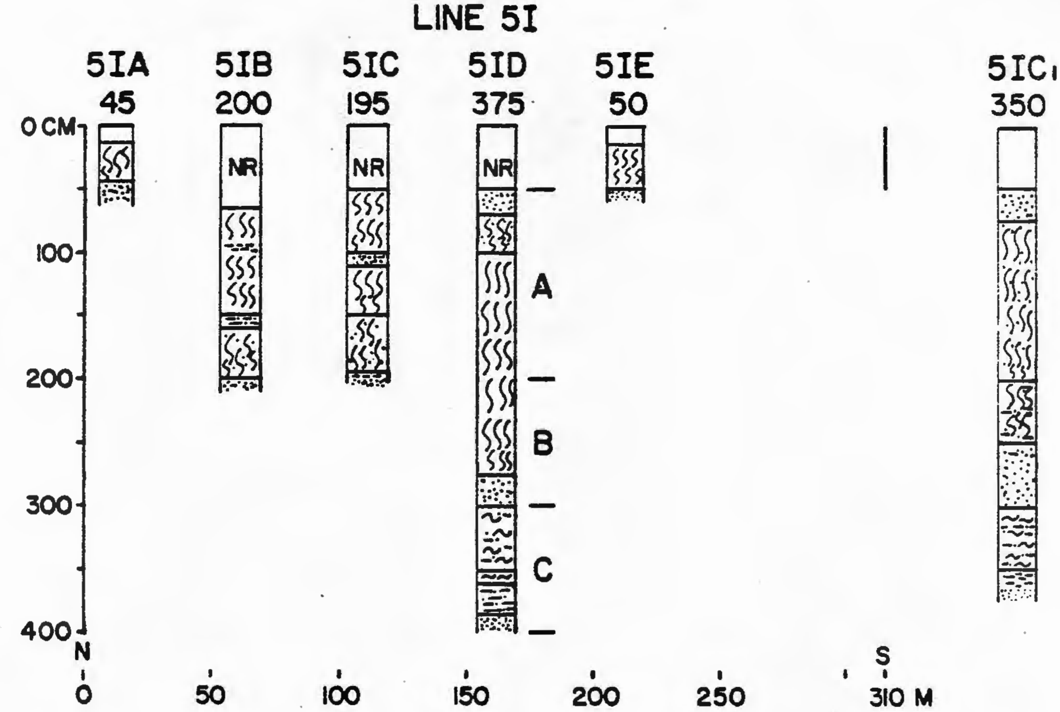


D. FRANKLIN SWAMP

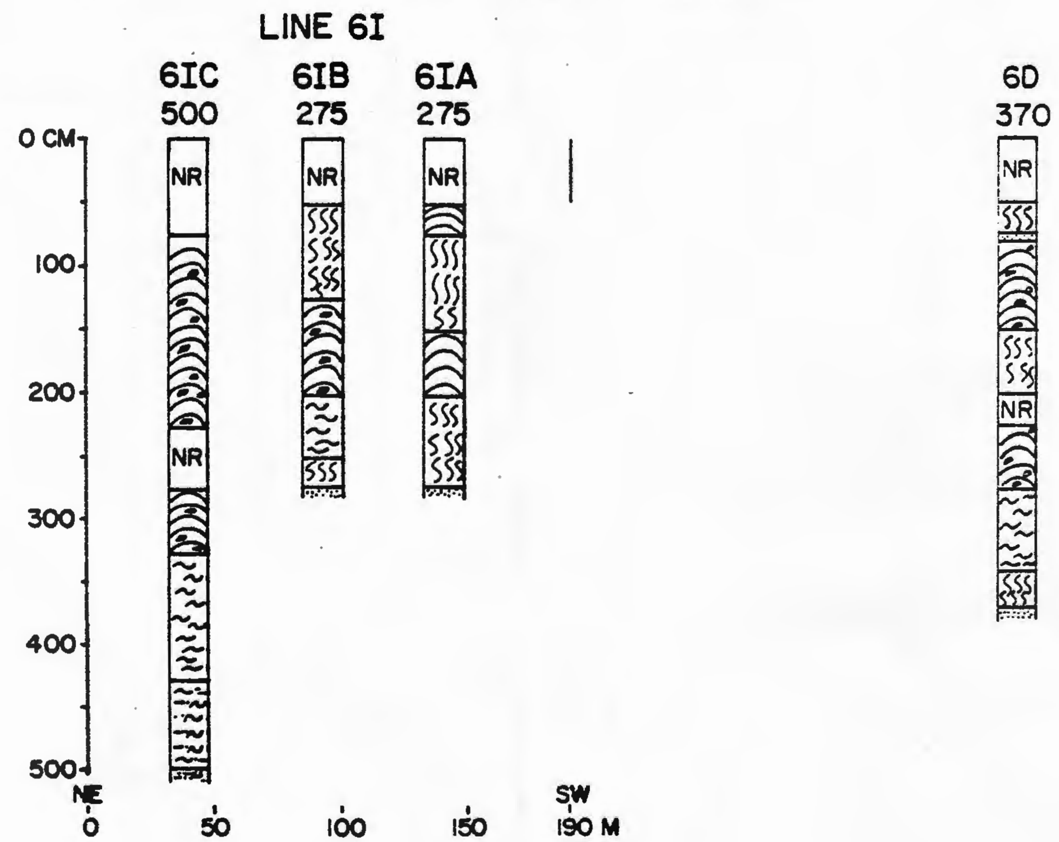




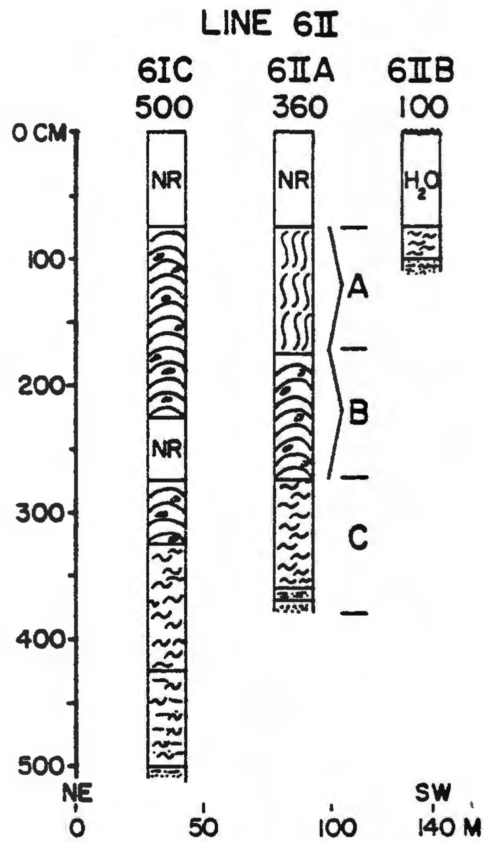
E. EAST GREAT SWAMP



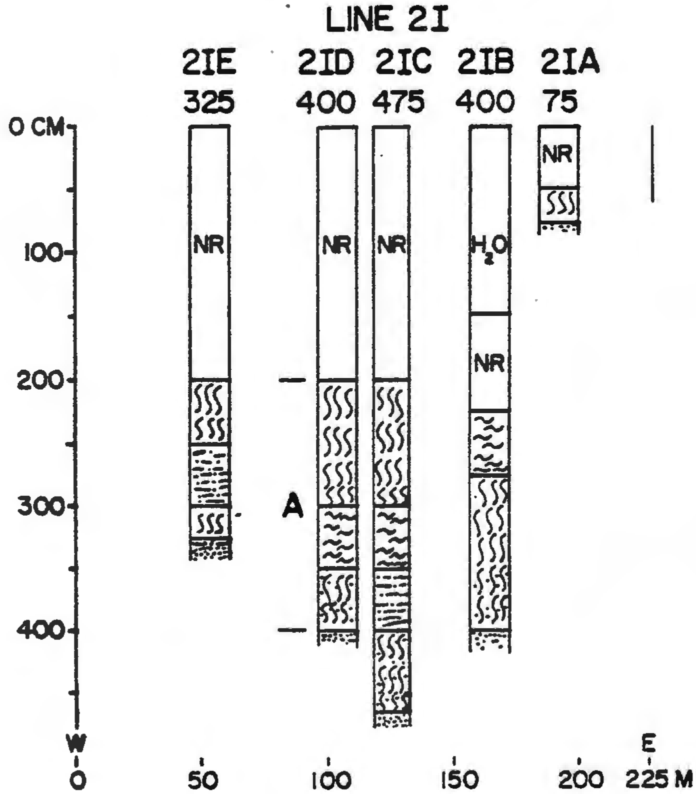
F. WEST GREAT SWAMP

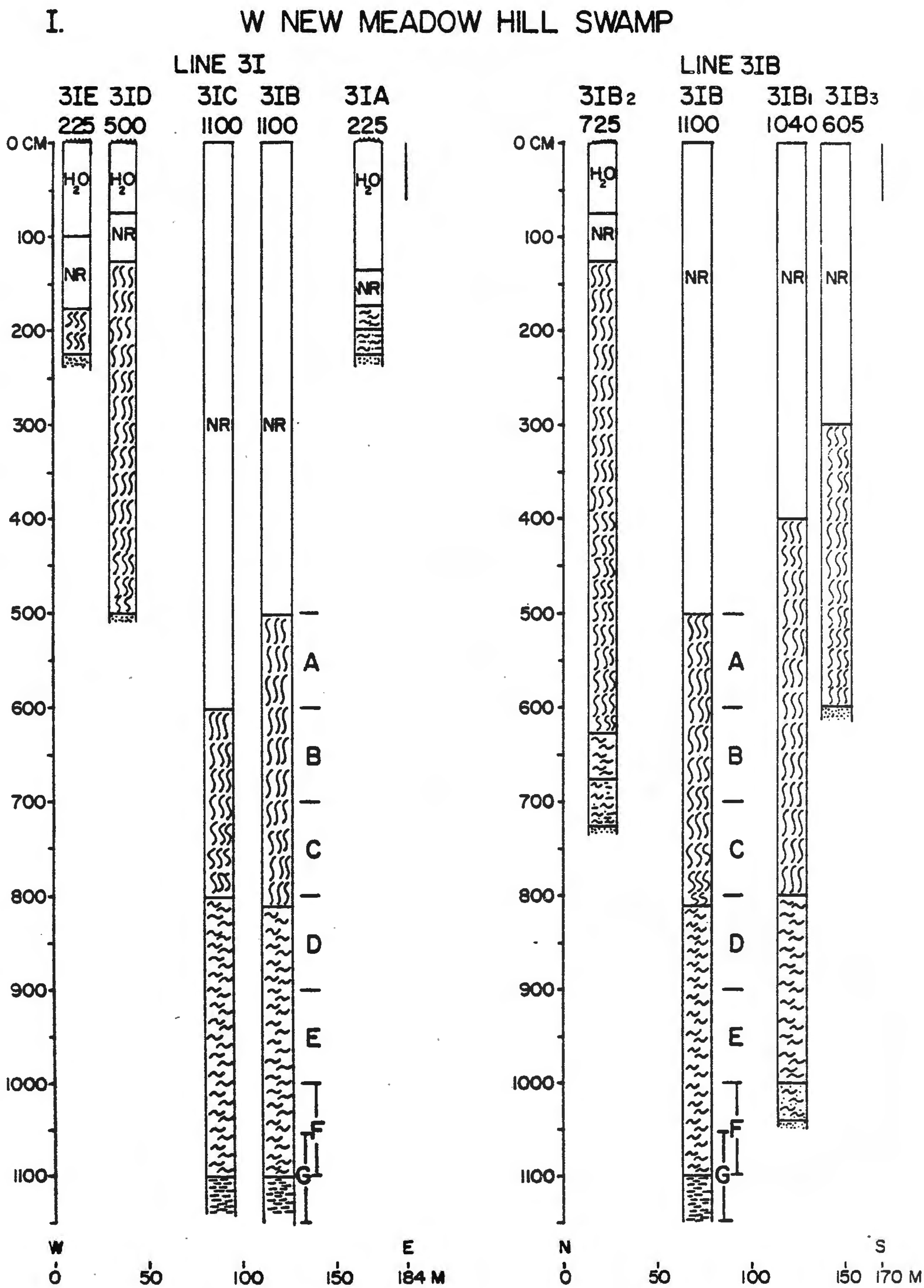


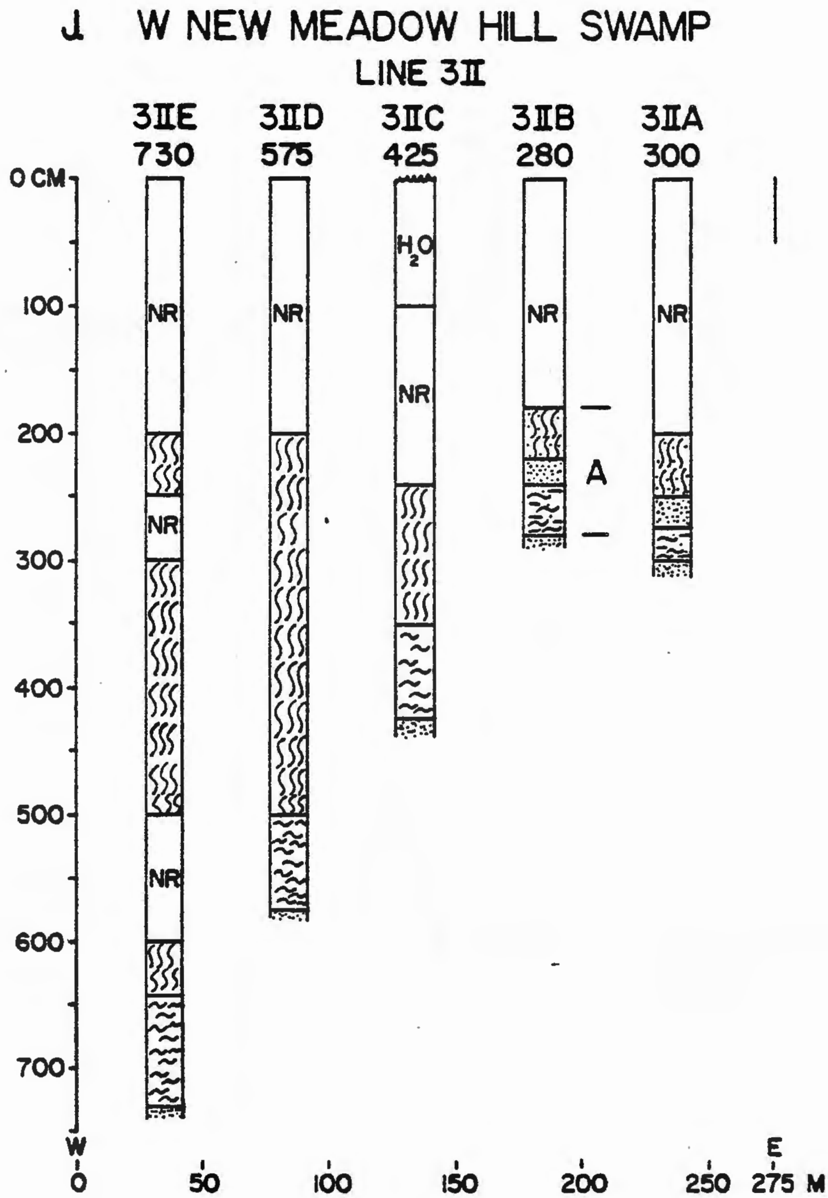
G. WEST GREAT SWAMP

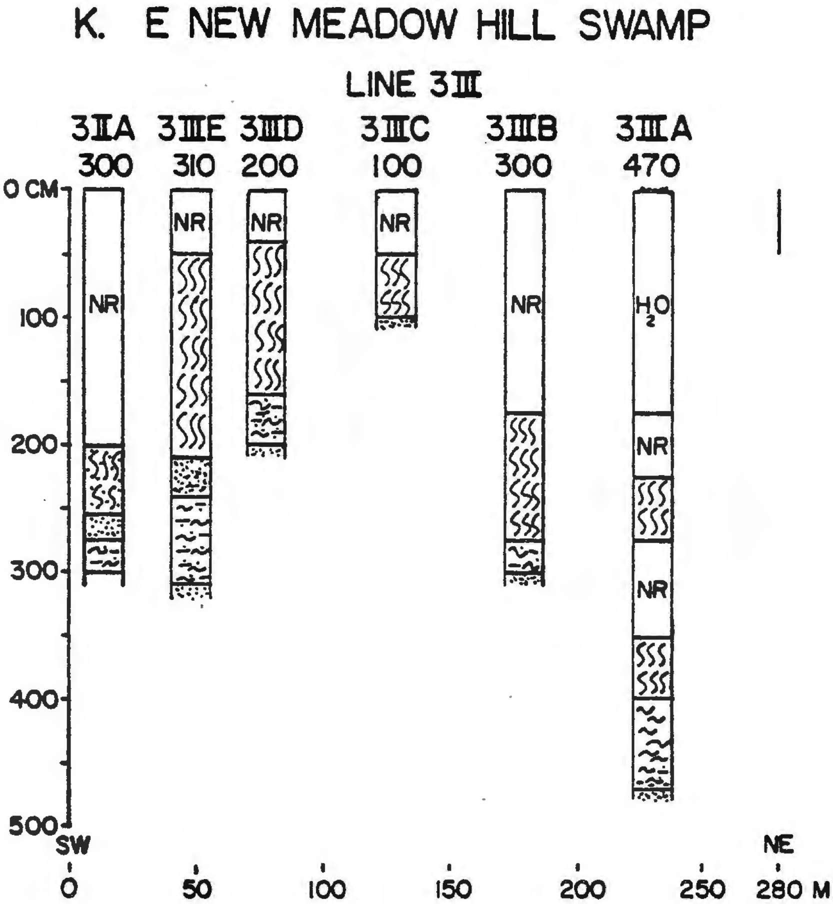


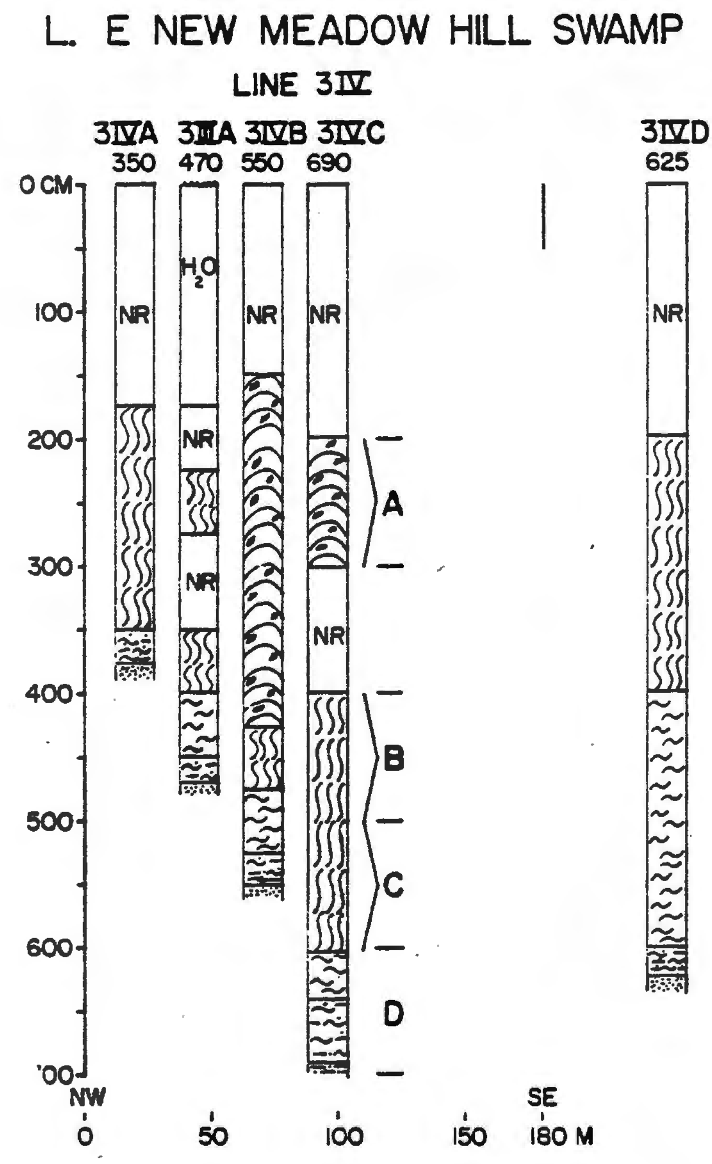
H. NEPTUNE SEGMENT




I.
W NEW MEADOW HILL SWAMP
LINE 3I
3IE 225
3ID 500
3IC 1100
3IB 1100
3IA 225
LINE 3IB
3IB2 725
3IB 1100
3IB1 1040
3IB3 605
0 CM
100
200
300
400
500
600
700
800
900
1000
1100
H_2O
NR
A
B
C
D
E
F
G
W
E
0
50
100
150
184 M
N
S
170 M


J. W NEW MEADOW HILL SWAMP
LINE 3II
3IIE
730
3IID
575
3IIC
425
3IIB
280
3IIA
300
0 CM
100
200
300
400
500
600
700
NR
H2O
A
W
E
0
50
100
150
200
250
275 M


K. E NEW MEADOW HILL SWAMP
LINE 3III
3IIA 300
3IIIE 310
3IIID 200
3IIIC 100
3IIIB 300
3IIIA 470
0 CM
100
200
300
400
500
NR
H2O
SW
NE
0
50
100
150
200
250
280 M



L. E NEW MEADOW HILL SWAMP
LINE 3IV
3IVA 350
3IIIA 470
3IVB 550
3IVC 690
3IVD 625
0 CM
100
200
300
400
500
600
700
H_2O
NR
A
B
C
D
NW
SE
0
50
100
150
180 M

APPENDIX 3

IN situ Peat Volume of Investigated Wetlands

AMBROSE SWAMP Total Area: 2.59 ha

Isopach Interval	Volume (m^3)
0-100*	12,500
100-200 cm	17,400
200-300	13,900
300-400	10,300
400-500	6,300
500-600	4,000
600-700	2,320
700-800	1,500
800-900	600
900-950	150
GRAND TOTAL VOLUME	69,150

FRANKLIN SWAMP Total Area: 7.89 ha

Isopach Interval	Volume (m^3)
0-100 *	32,300
100-200	36,700
200-300	22,100
300-400	15,600
400-500	11,500
500-600	8,300
600-700	5,700
700-800	3,300
GRAND TOTAL VOLUME:	135,500

*50 cm thickness used

GREAT SWAMP Total Area: 4.78 ha

EAST GREAT SWAMP Area: 2.10 ha

Isopach Interval	Volume (m^3)
0-100*	10,300
100-200 cm	8,840
200-300	3,500
300-350	750
Total Volume:	23,250

WEST GREAT SWAMP Area: 1.78 ha

0-100*	9,000
100-200 cm	13,000
200-300	9,100
300-400	4,600
400-500	1,200
500-600	130
Total Volume:	37,030

NEPTUNE SEGMENT Area: 0.90 ha

Interval	Volume (m^3)
0-100*	4,400
100-200 cm	2,600
200-300	1,000
Total Volume:	8,000

GRAND TOTAL VOLUME: 69,280

NEW MEADOW HILL SWAMP Total Area: 5.76 ha

WEST NEW MEADOW HILL SWAMP Area: 3.64 ha

Isopach Interval	Volume (m^3)
0-100*	18,400
100-200 cm	20,900
200-300	15,200
300-400	11,400
400-500	7,800
500-600	4,200
600-650	540
Total Volume:	78,440

EAST NEW MEADOW HILL SWAMP Area: 2.12 ha

Isopach Interval	Volume (m^3)
0-100*	10,600
100-200 cm	11,200
200-300	6,800
300-400	3,800
400-450	750
Total Volume:	33,150

GRAND TOTAL VOLUME: 111,590

APPENDIX 4

Fuel Analyses

Performed by U.S. Department of Energy

Coal Preparation Laboratory

Core	Peat Type	Depth (m)	PROXIMATE ANALYSIS %Total Moisture	MOISTURE FREE %Volatile Matter	%Fixed Carbon	%Ash	ULTIMATE ANALYSIS %Hydrogen	%Carbon	%Oxygen	%Nitrogen	%Sulfur	Heating Value (BTU/lb) Moist free	35% moist
Ambrose Swamp													
7IA,A	Moss	3-4	92.10	56.76	32.54	10.70	4.47	52.43	29.46	2.02	0.93	9136	5938
B	Moss	4-5	91.39	53.63	27.54	18.83	4.62	48.29	27.38	0.04	0.85	8413	5468
C	Reed-sedge	5-6	90.99	52.95	24.27	22.78	4.71	46.14	23.22	2.17	0.98	8185	5320
D	Reed-sedge	6-7	90.32	53.00	24.13	22.87	4.61	46.19	23.04	2.33	0.96	8228	5348
E	Reed-sedge	7-8	89.98	46.77	21.52	31.71	4.06	40.81	20.31	2.18	0.92	7165	4657
F	Sedimentary	8-8.7	85.44	31.45	14.60	53.95	2.84	26.90	14.29	1.39	0.62	4683	3044
Franklin Swamp													
4IIC,A	Sandy R-S	1-2	83.81	29.67	11.36	58.97	2.32	24.38	12.31	1.40	0.62	4016	2610
B	Sandy R-S	2-3	87.83	39.14	15.57	45.29	3.41	31.74	16.66	2.03	0.87	5460	3549
C	Sedimentary	3-4	87.62	41.28	17.65	41.07	3.59	34.43	17.97	1.90	1.04	5926	3852
D	Sedimentary	4-5	88.42	38.08	14.49	47.43	3.42	29.47	16.73	2.01	0.94	5347	3476
E	Sandy R-S	5-6	82.84	28.73	10.69	60.58	2.36	21.48	13.53	1.45	0.60	3895	2532
F	Silty Sed.	6-7	81.27	31.97	13.22	54.81	2.75	26.65	13.65	1.68	0.47	4686	3046
G	Silty Sed.	7-7.8	76.84	24.94	10.06	65.00	2.40	20.24	10.74	1.26	0.36	3501	2276
East Great Swamp													
5ID,A	Sandy R-S	0.5-2	68.94	18.61	8.21	73.18	1.58	16.19	8.03	0.58	0.43	2648	1721
B	Sandy R-S	2-3	62.32	10.78	3.88	85.34	0.83	7.44	5.77	0.28	0.34	1151	748
C	Silty Sed.	3-4	62.82	10.24	2.41	87.35	0.81	5.86	5.41	0.32	0.26	887	577
West Great Swamp													
6IIA,A	Reed-sedge	0.7-1.7	86.76	51.35	31.17	17.48	4.44	50.65	25.59	1.24	0.58	8450	5493
B	Moss	1.7-2.7	91.67	54.33	35.00	10.67	4.60	54.99	27.59	1.40	0.76	9169	5960
C	Silty Sed.	2.7-3.7	73.14	12.56	5.08	82.36	0.98	9.90	5.94	0.58	0.24	1723	1120
Neptune Segment													
2ID,A	Sandy R-S	2-4	79.31	26.13	12.60	61.27	2.27	23.30	11.78	0.93	0.44	3854	2505

			PROXIMATE ANALYSIS				ULTIMATE ANALYSIS						
				MOISTURE FREE									
Core	Peat Type	Depth (m)	%Total Moisture	%Volatile Matter	%Fixed Carbon	%Ash	%Hydrogen	%Carbon	%Oxygen	%Nitrogen	%Sulfur	Heating Value (BTU/1b) Moist free	35% moist
West New Meadow Hill Swamp													
3IB,A	Reed-sedge	5-6	89.29	46.80	26.39	26.81	4.10	41.26	23.85	1.91	2.08	7026	4567
B	Reed-sedge	6-7	88.74	42.57	23.97	33.46	3.83	38.16	21.39	1.84	1.32	6524	4241
C	Reed-sedge	7-8	88.27	44.79	24.20	31.01	4.04	39.02	22.91	1.81	1.21	6716	4365
D	Sedimentary	8-9	86.83	40.33	23.06	36.61	3.58	37.25	19.89	1.82	0.84	6413	4168
E	Sedimentary	9-10	87.30	41.81	21.23	36.96	3.74	36.60	20.06	1.79	0.84	6330	4115
F	Sedimentary	10-11	87.27	38.18	20.05	41.77	3.37	34.04	18.26	1.82	0.74	5925	3851
G	Sedimentary	10.5-11.5	87.37	39.04	20.17	40.79	3.57	34.12	18.86	1.79	0.87	6001	3901
3IIB,A	Sandy R-S	1.8-2.8	70.43	21.29	10.86	67.85	2.12	20.06	8.95	0.61	0.42	3404	2213
East New Meadow Hill Swamp													
3IVC,A	Moss	2-3	89.31	59.96	31.14	8.90	5.30	54.99	28.26	1.61	0.94	9560	6214
B	Reed-sedge	4-5	90.45	53.96	26.65	19.39	4.70	48.26	24.89	1.88	0.87	8380	5447
C	Reed-sedge	5-6	91.00	51.24	26.71	22.05	4.65	46.79	23.65	2.01	0.85	8182	5318
D	Silty Sed.	6-7	81.06	23.99	9.27	66.74	2.29	19.09	9.52	2.01	0.35	3209	2086
E	Silty Sed.	6.3-7.3	67.91	13.31	4.79	81.00	1.30	10.11	6.05	0.47	0.17	1519	987